ESPOO 2006 VTT PUBLICATIONS 594

Marika Lyly

Added ß-glucan as a source of fibre for consumers

VTT PUBLICATIONS 594

Added β-glucan as a source of fibre for consumers

Marika Lyly

VTT

ACADEMIC DISSERTATION

To be presented with the permission of the Faculty of Agriculture and Forestry of the University of Helsinki, for public criticism in Walter Hall, Viikki, on 3rd March, 2006, at 12 o'clock noon.

ISBN 951–38–6700–5 (soft back ed.)
ISSN 1235–0621 (soft back ed.)

ISBN 951–38–6701–3 (URL: http://www.vtt.fi/inf/pdf/)
ISSN 1455–0849 (URL: http://www.vtt.fi/inf/pdf/)

JULKAISIJA – UTGIVARE – PUBLISHER

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Cover picture: Päivi Vahala. Photos by VTT.

Technical editing Maini Manninen

Otamedia Oy, Espoo 2006

Lyly, Marika. Added β-glucan as a source of fibre for consumers. Espoo 2006. VTT Publications 594. 96 p. + app. 50 p.

Keywords dietary fibres, β-glucans, fibre enrichment, consumer acceptance, functional food, beverages, soups, sensory quality, healthy diet

Abstract

The intake of dietary fibre does not currently meet the recommendations in many Western countries. However, a diet abundant in dietary fibre has been linked with a reduced risk of many diseases, such as type 2 diabetes, colorectal cancer and cardiovascular disease. For that reason, dietary fibre can be considered as an essential component in a health-promoting diet and it is important to find new ways to increase its intake. β-glucan could be an effective type of dietary fibre when added into foods because of its proven health effects; it has been shown to reduce elevated blood cholesterol levels and balance blood glucose and insulin response after meals.

Adding physiologically effective amounts of β-glucan into foods may be difficult as regards the processing and sensory quality of the foods, as consumers are not willing to compromise on taste in foods. The general aim of this thesis was to investigate whether providing foods enriched with β-glucan would be a feasible strategy for improving consumers' dietary fibre intake. The more detailed objectives were to study Finnish consumers' views on dietary fibre and possible obstacles to improving the intake of dietary fibre, the technical feasibility of a prototype beverage and a soup containing β-glucan as regards their sensory quality, and the consumer acceptance of these foods with information about their health effects in Finland, France and Sweden.

The results showed that Finnish respondents (N = 125) considered dietary fibre important for their health, although it was not spontaneously mentioned as an element of a health-promoting diet. A group of respondents overestimated their dietary fibre intake compared to their actual intake as estimated using a fibre intake test. This misperception can be an obstacle to improving the quality of the diet. The respondents did not know what was the recommended intake of dietary fibre (in grams), but they could name relevant sources of fibre in the diet.

Adding oat or barley β-glucan into beverages and ready-to-eat soups affected their sensory characteristics by making them thicker and suppressing some flavour attributes with increasing concentrations of β-glucan, as evaluated by an experienced sensory panel. Low molecular weight β-glucan was easier to add into products at higher concentrations as regards the sensory characteristics. The importance of the high molecular weight of β-glucan in terms of its physiological efficacy, however, is important to consider. Freezing did not affect the sensory characteristics of soups containing β-glucan.

Consumer acceptance of beverages and ready-to-eat frozen soups was studied in Finland, France and Sweden among over-40-year-olds (N = 1157). The results showed that a health claim gave a small additional value to beverages and soups with added β-glucan, but liking for the products was the strongest determinant for the willingness to use them. There were no differences between men's and women's willingness to use these foods. Respondents who were concerned about their blood cholesterol and/or glucose levels were more willing to use beverages but not soups with health claims. Only in Sweden were the elderly more willing to use beverages with health claims compared to younger respondents; while in Finland and France no differences were found between age groups in the willingness to use beverages. There were no differences between age groups in the willingness to use soups in any of the countries. It does not seem likely that consumers would be ready to pay much extra for functional beverages and soups.

In conclusion, the present study demonstrated that Finnish consumers perceive fibre as being important for their health. Beverages and soups with added β-glucan were feasible regarding their sensory properties and thus would make potential carrier products for added β-glucan. β-glucan as an additional fibre source gave a small added value to beverages and soups but the taste of the products was the most important factor affecting the willingness to use these foods. Palatable fibre-enriched foods could be a possible approach to increase fibre intake as part of a normal diet. Further research would be needed to investigate the actual role of fibre-enriched products in the total intake of dietary fibre.

Academic dissertation

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Preface

The study was carried out at VTT Biotechnology during the years 2001–2005. The majority of the research was part of the VTT research programme 'Tailored Technologies for future foods' and was mainly carried out as part of a European research project entitled "Design of foods with improved functionality and superior health effects using cereal betaglucans" (QLRT-2000-00535), financially supported by the European Community (EC) within the 5th Framework Programme under the Quality of Life and Management of Living resources, Key Action 1. The financial support is gratefully acknowledged.

I thank Professor Juha Ahvenainen, Technology Director of VTT's Biotechnology Cluster, for providing excellent work facilities and financial support. I warmly thank Professor Leena Räsänen and Professor Marja Mutanen, both from the Department of Nutrition at the University of Helsinki, for their encouragement and comments. I would especially like to thank the reviewers of this thesis, Ph.D. Armand Cardello and Docent Ritva Järvinen, for their extremely valuable effort in giving constructive comments and criticisms, and for creating a fruitful dialogue during the reviewing process.

I am most grateful to Dr. Liisa Lähteenmäki for encouraging me to start this thesis and for supervising me through all the steps in the work and for sharing her wide expertise in this area. I am very grateful to Professor Kaisa Poutanen for supervision and continuous dynamic ideas. This work would not have been possible without the co-operation and support of several colleagues. I wish to express my appreciation to the rest of my co-authors in Publications I–IV: Dr. Karin Autio, Kaisu Honkapää, Dr. Katariina Roininen, Dr. Marjatta Salmenkallio-Marttila and Dr. Tapani Suortti at VTT Biotechnology, Ulla Rauramo from The Finnish Bread Information and Eija Soini. I warmly thank my closest colleagues Anne Arvola, Heidi Eriksson, Dr. Raija-Liisa Heiniö, Johanna Kuosmanen, Tuija Kössö, Piritta Lampila, Pirkko Nousiainen, Dr. Katariina Roininen, Dr. Nina Urala and Ulla Österlund for keeping the team spirit up. Pirkko, Heidi and Ulla, your assistance was irreplaceable in handling the hundreds of soup and beverage samples! Particularly Nina, thank you for sharing this process with me during the bright and dark days (in the end I'm glad that we did not press the cancel button). In addition, I wish to thank our partners in the EU project for collaboration. In particular, I would like to thank Jörgen Holm, Findus R & D, for providing the soups in Studies III and IV, Angeliki Öste-Triantafyllou and Rickard Öste at CEBA Foods AB for providing the β-glucan preparations in Studies II–IV and Markus Wydra, Döhler Euro Citrus GmbH for providing the beverage bases in Studies II and IV. I also wish to thank Kaisa Vesivalo from Translation Services Noodi for revising the English language in this thesis quickly and flexibly.

I owe my dearest thanks to my family, relatives and friends for their encouragement, relaxing moments and shared experiences. In particular, my mother Marjanna has been an extremely important help in taking care of little Pihla. Finally, I would like to express my warmest gratitude to my own family – Janne and Pihla – for showing and reminding me what the most important things in life really are.

Espoo, February 2006

Marika Lyly

List of original publications

The present thesis is based on the following publications, which will be referred to in the text by their Roman numerals (I–IV). Unpublished data is also presented.

I Lyly, M., Soini, E., Rauramo, U. and Lähteenmäki, L. 2004. Perceived role of fibre in a healthy diet among Finnish consumers. *Journal of Human Nutrition and Dietetics* 17, 231–239.

II Lyly, M., Salmenkallio-Marttila, M., Suortti, T., Autio, K., Poutanen, K. and Lähteenmäki, L. 2003. Influence of oat ß-glucan preparations on the perception of mouthfeel and on rheological properties in beverage prototypes. *Cereal Chemistry* 80, 536–541.

III Lyly, M., Salmenkallio-Marttila, M., Suortti, T., Autio, K., Poutanen, K. and Lähteenmäki, L. 2004. The sensory characteristics and rheological properties of soups containing oat and barley β-glucan before and after freezing. *Lebensmittel-Wissenschaft und Technologie* 37, 749–761.

IV Lyly, M., Roininen, K., Honkapää, K., Poutanen, K. and Lähteenmäki, L. Factors influencing consumers' willingness to use beverages and ready-to-eat frozen soups containing oat ß-glucan in Finland, France and Sweden. *Food Quality and Preference.* In press.

Research input and authorship of articles

Marika Lyly's dissertation is a summary of research reported in four (I–IV) appended articles. The research input and authorship of the articles is as follows:

I. *Lyly, M., Soini, E., Rauramo, U. and Lähteenmäki, L. 2004. Perceived role of fibre in a healthy diet among Finnish consumers. Journal of Human Nutrition and Dietetics 17, 231–239.*

The planning of this study as well as the data analysis was carried out by Marika Lyly, M.Sc., and Dr. Liisa Lähteenmäki. The interviews were carried out and data coded by Eija Soini, M.Sc. The study was supervised by Dr. Liisa Lähteenmäki and with other authors she participated in the writing of the manuscript by giving comments and suggestions. The author of the present thesis had the main responsibility for preparing and writing the article.

II. *Lyly, M., Salmenkallio-Marttila, M., Suortti, T., Autio, K., Poutanen, K. and Lähteenmäki, L. 2003. Influence of oat ß-glucan preparations on the perception of mouthfeel and on rheological properties in beverage prototypes. Cereal Chemistry 80, 536–541.*

The planning of this study as well as the data analysis was carried out by Marika Lyly, M.Sc., and Dr. Liisa Lähteenmäki. Samples were prepared by the technicians at VTT. Viscosity measurement was performed by Dr. Marjatta Salmenkallio-Marttila and molecular weight analyses by Dr. Tapani Suortti. The study was supervised by Dr. Liisa Lähteenmäki and Prof. Kaisa Poutanen and with other authors they participated in the writing of the manuscript by giving comments and suggestions. The author of the present thesis had the main responsibility for preparing and writing the article.

III. *Lyly, M., Salmenkallio-Marttila, M., Suortti, T., Autio, K., Poutanen, K. and Lähteenmäki, L. 2004. The sensory characteristics and rheological properties of soups containing oat and barley ß-glucan before and after freezing. Lebensmittel-Wissenschaft und Technologie 37, 749–761.*

The planning of this study as well as the data analysis was carried out by Marika Lyly, M.Sc., and Dr. Liisa Lähteenmäki. Preparation of the samples was carried out by our technicians at VTT. Viscosity measurement was performed by Dr. Marjatta Salmenkallio-Marttila and Tessa Kuuva, M.Sc. Dr. Tapani Suortti performed molecular weight analyses and wrote a paragraph about them. The study was supervised by Dr. Liisa Lähteenmäki and Prof. Kaisa Poutanen and with other authors they participated in the writing of the manuscript by giving comments and suggestions. The author of the present thesis had the main responsibility for preparing and writing the article.

IV. *Lyly, M., Roininen, K., Honkapää, K.., Poutanen, K. and Lähteenmäki, L. Factors influencing consumers' willingness to use beverages and ready-meal frozen soups containing oat ß-glucan in Finland, France and Sweden. Food Quality and Preference. In press.*

The planning of the study was carried out by Marika Lyly, M.Sc., and Dr. Liisa Lähteenmäki. The data analysis was performed by Marika Lyly, M.Sc., Kaisu Honkapää, M.Sc., Dr. Katariina Roininen and Dr. Liisa Lähteenmäki. Sample distribution to consumers was organised by the technicians at VTT. The study was supervised by Dr. Liisa Lähteenmäki and with other authors she participated in the writing of the manuscript by giving comments and suggestions. The author of the present thesis had the main responsibility for preparing and writing the article.

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Publications I–IV

1. Introduction

In recent years, the increasing prevalence of public health problems related to a sedentary lifestyle has been widely discussed in developed countries. Obesity, type II diabetes and metabolic syndrome are becoming increasingly common health problems that require a lot of resources from the public health care system (WHO 2003). Lifestyle factors such as exercise, smoking, inappropriate diet quality and energy intake that is too high compared to energy consumption, in addition to hereditary factors, are key risk factors to these disorders. Additionally, as life expectancy is increasing, the well-being of the ageing population is a key target.

Thus, diet is one of the lifestyle factors that can be improved in order to lower diet-related disease risk factors. Basically, European consumers know what elements belong to a health-promoting diet, ‘more fruit and vegetables’, ‘less fat’, ‘balance and variety’ (Margetts et al. 1997), as recommended by nutritionists, but the increasing morbidity rates of diet-related disorders indicate that, in practice, people’s diet does not follow the recommendations. The role of government is to provide nutritional goals (Figure 1), but the general education or information campaigns are not necessarily effective enough as such in improving dietary habits. As an example, the “five-a-day” campaign, which encouraged an increase in the intake of vegetables and fruit to five portions per day, has not succeeded very well in the USA or in the UK (Lambert et al. 2002).

On the other hand, it is the role of the food industry to provide appropriate products for consumers and also to communicate about the product benefits (Figure 1). Thus, the nutritional goals set by government or other authorities are at the level of the overall diet, while the food industry provides products and product-based information. The challenge for consumers is to gather a diet from the individual products available on the market, although the nutritional goals are at the level of the overall diet.

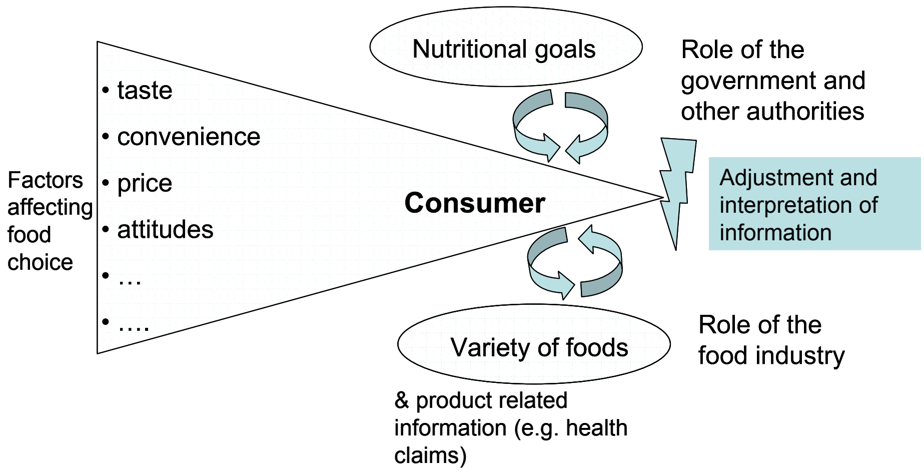

Figure 1. Actors and responsibilities relating to consumers' food choice.

Among the many components of diet, the role of dietary fibre in health has been investigated in numerous studies. Intake of fibre has been associated with reduced risk of many diseases, such as colorectal cancer (Bingham et al. 2003), cardiovascular disease (Pereira et al. 2004) and type 2 diabetes (Meyer et al. 2000). Therefore, it can be regarded as one of the key components in a health-promoting diet.

However, dietary fibre intake is not adequate in many developed countries and new ways to improve the intake should be invented. Dietary habits are changing and the consumption of ready-made foods has increased. This may lead to a decreased intake of dietary fibre if pre-prepared and processed foods contribute significantly to energy intake (Burns et al. 2002). At the same time, the consumption of traditional sources of fibre is decreasing. Therefore, one possibility is to add dietary fibre into foods that traditionally are not relevant sources of fibre in the diet, for instance, beverages.

β-glucan, a water-soluble fibre in oat and barley, could be a good dietary fibre alternative to be added into foods because of its proven health effects. Oat has been shown to have a balancing effect on post-prandial blood glucose and insulin levels (Wood et al. 1994) and to lower blood cholesterol levels (Ripsin et al. 1992). However, adding β-glucan into foods may be problematic from the food processing and sensory quality point of view. β-glucan produces high viscosity (Wood and Beer 1998), which may be a difficult sensory characteristic in foods. On the other hand, viscosity is crucial for the physiological efficacy of β-glucan (Wood et al. 1994).

In order for consumers to benefit from the positive health effects, foods with high dietary fibre content must be bought and consumed regularly. How can the selection and use of foods with health benefits be enhanced? Taste is one of the most important factors affecting food choice (Glanz et al. 1998). Hence, taste and the overall sensory quality of foods must be faultless and acceptable. In addition, consumers need to be better informed about foods with a high dietary fibre content by providing appropriate and effective information about the benefits of the products. It is crucial to communicate about the health effects, because they are not readily evident in the product itself. In order to successfully do this, the factors behind consumers' willingness to use modified foods must be identified. Specifically, in order to improve dietary fibre intake, consumers' perceptions of fibre and the possible obstacles to improving the intake of fibre should be investigated.

The general aim of this thesis was to investigate whether providing foods with added β-glucan would be a feasible strategy for improving consumers' dietary fibre intake.

1.1 Dietary fibre in a health-promoting diet

1.1.1 Definition and health benefits of dietary fibre

Dietary fibre is the non-digestible part of plant food and it includes a group of different compounds of varied nature. Trowell (1972) defined fibre as the skeletal remnants of plant cells that are resistant to hydrolysis by enzymes. In 2001 (Anonymous 2001), dietary fibre was defined as follows: "Dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation."

Dietary fibre can be classified according to its water solubility. Soluble fibres include mainly gums, pectins and mucilages while the insoluble fibres include cellulose, hemicellulose and lignin. According to another classification based on the chemical structure, the constituents of dietary fibre are non-starch polysaccharides and resistant oligosaccharides, analogous carbohydrates (e.g. indigestible dextrins, synthesised carbohydrate compounds), lignin and substances associated with the non-starch polysaccharide and lignin complex in plants (e.g. waxes, phytate, tannins, saponins) (Anonymous 2001). Different fibre types are fermented by bacteria in the colon. Water-soluble fibres are usually almost completely fermented while insoluble fibres are only partly fermented. Another important characteristic is the water-retention capacity, with the pectins, mucilages and hemicellulose having the best capacity.

Dietary fibre is collectively acknowledged to be one of the key factors in a health-promoting diet as the link between intake of dietary fibre and the reduced risk of many diseases is established in several studies. Increased dietary fibre intake decreases serum cholesterol levels (Brown et al. 1999) and reduces the risk of cardiovascular diseases (Pietinen et al. 1996, Rimm et al. 1996, Jenkins et al. 1998, Liu et al. 2002, Pereira et al. 2004). Intake of total dietary fibre (Bingham et al. 2003), especially from cereal and grain products (Hill 1998, Jansen et al. 1999) is also positively associated with a decreased risk of colorectal cancer and adenomas (Peters et al. 2003). However, a recent meta-analysis indicates a less significant effect of dietary fibre on the risk of colorectal cancer (Park et al. 2005). Dietary fibre has also been proven to have a protective role in the development of diabetes (Meyer et al. 2000, Schulze et al. 2004). In addition, a high intake of dietary fibre is associated with increased frequency of bowel movements (Sanjoaquin et al. 2004) and it relieves constipation (reviewed by Dohnalek 2004), a condition that affects the quality of everyday life of many individuals.

The mechanism behind the effect of dietary fibre on health is not fully understood, and the evidence is based on associations between the prevalence or incidence of a particular disease and the amount of fibre in the diet. A diet high in dietary fibre may be low in energy content, saturated fat content or alter the absorption of harmful substances from the food, which may also partly explain the effect of dietary fibre on health. In adults, it is unlikely that a diet would have too high a fibre content. However, a high fibre diet may cause flatulence (Bolin & Stanton 1998), which may be inconvenient.

1.1.2 Recommended and current intake and sources of dietary fibre in the diet

Alarmingly, the intake of dietary fibre in many Western countries does not meet recommendations and it is believed that its intake is still decreasing in many countries (Miller-Jones 2004). In Table 1 the intake and sources of fibre and the recommended intake in selected countries is described with the aim of describing dietary fibre intake in different Western countries. The data in these studies were mainly collected in the 1990s (with some in the 1980s) using different methods (food frequency questionnaire, 24-h recall, weighted records). Due to the different dietary methods used, differences in the methods used to analyse the dietary fibre composition of foods, and differences in study populations (size, age range), comparison of the values should be made with caution. In all these countries, dietary fibre intake does not meet either the recommendations of the WHO (World Health Organisation) or of the country itself. The WHO's recommendation for total dietary fibre intake is > 25 g/day (WHO 2003). Women tend to have more fibre-dense diets than men, although men's average intake of dietary fibre is usually higher because of the higher energy intake. For example, in a Finnish nationally representative study, the fibre density of men's and women's diets was 2.5 g/MJ and 2.9 g/MJ, respectively, (Männistö et al. 2003).

The main sources of dietary fibre in the diet are culture dependent and vary slightly between countries, but Table 1 shows that bread, cereals, vegetables and fruit and berries are the most important sources of dietary fibre.

Apparent reasons for the decrease in fibre intake are a reduction in energy expenditure and food intake and changed eating habits. For example, in Finland, rye is a typically significant source of fibre and the consumption of rye products is the main indicator for high fibre intake (Valsta 1999). However, the consumption of rye per capita has decreased between 1970 and 2003 from 23.3 to 14.6 kg/capita/year (Statistics Finland 2004).

As intake of dietary fibre is positively associated with proven health benefits, there is a need to improve the intake. A 'traditional' way of doing this would be to increase the consumption of high-fibre foods, such as wholegrain bread and cereals. A 'new' way could be to add fibre to foods which traditionally do not contain dietary fibre, but which are consumed more and more in the current diet of many countries. For example, consumers' interest in ready-to-eat foods and functional beverages is increasing (Sloan 2005), and their dietary fibre content could possibly be modified.

Table 1. Intake and sources of fibre in selected Western countries and the recommended intake (g/day).

Country	Study population	Men (g/day)	Women (g/day)	All (g/day)	Main sources	Reference	Recommendation (g/day)
Austria	N = 4661, 4–56 + y			18		Koenig and Elmadfa (1999)	30 g/day (National recommendation)
Belgium	N = 11302, 25–74 y	8.4 g/1000 kcal/day	9.2 g/1000 kcal/day			De Henauw and De Backer (1999)	15–22 g/1000 kcal/day (National recommendation)
Denmark		22	18		Cereals 62% Vegetables 24% Fruit 12%	Miller-Jones (2004)*	
Finland	N = 2007, 25–64 y	21.8 (NSP)	18.5 (NSP)		Bread 50% Fruit and berries 14% Other cereals 11% Vegetables 10%	Männistö et al. (2003)	25–35 (NSP) (National Nutrition Council 2005)
France	N = 4080, 45–65 y	21.0 (DF)	17.1 (DF)		Cereals 30–35% Vegetables 20–24% Fruit 19–22%	Lairon et al. (2003)	25–35 (DF) (National recommendation)
Germany		21.9	19.5		Bread	Miller-Jones (2004)*	
Greece	N = 470, 18–64 y			18.2		Moschandreas and Kafatos (1999)	≥ 25 g/day (National recommendation)
Ireland	N = 1379, 18–64 y	16.7 (NSP) 23.2 (DF)	13 (NSP) 17.4 (DF)	14.8 (NSP) 20.2 (DF)	Breads 30.7 % Potato 19.3% Vegetables 16.5%	Galvin et al. (2001)	18 (NSP) (National recommendation)
Netherlands				21		Gibney (2001)*	
Portugal	N = 489, ≥ 40 y			26.3 (DF)		Graca (1999)	27–40 g/day (National recommendation)
Spain				17		Gibney (2001)*	
Sweden	N = 1651, 15–74 y	18 (DF)	15 (DF)			Becker (1999)	25–35 (NSP) (Swedish Nutrition Recommendations 1997)
UK		20	20.4	20.3 (NSP)		Bingham et al. (2003)	18 (NSP) (National recommendation)
USA				13–15 g/d		Miller-Jones (2004)*	

NSP = Non-starch polysaccharides.
DF = dietary fibre.
* = review article; the author has gathered the information from various sources.

1.1.3 Consumers' perceptions of dietary fibre and barriers to increase the intake

In general, consumers have a positive perception of high-fibre products as regards their healthiness and nutritional value (Mialon et al. 2002). Dietary fibre is also recognised as an important target for modification in the diet. In an American study, 38% of the respondents reported having changed or to be currently changing their diet as regards fibre and 45% regarding fat (Auld et al., 1998). In addition, women, older participants, the better educated and respondents with diet-related disease were more likely to have made changes to their diets. Among Europeans, those who had changed their eating habits in the past 3 years had most frequently increased their consumption of fruit and vegetables and water and decreased their consumption of fat, energy intake ('calories') and sugar (European Opinion Research Group 2003). In the latter study, no questions were asked about changes in dietary fibre intake.

Despite the positive attitudes of consumers towards dietary fibre, a lack of more detailed knowledge about dietary fibre and its sources in the diet has been observed in many studies. Whichelow (1988) found British consumers to have a lack of basic understanding of the term dietary fibre, because many of the respondents in her study believed that animal products were a source of dietary fibre. This was also the case in the study of Sobal and Cassidy (1993) among Americans. Less than one-third of the respondents could correctly classify at least eight foods according to their fibre content among ten food items of which five contained fibre and five did not (Whichelow 1987, 1988). The higher educated and females had a better knowledge of dietary fibre (Whichelow, 1988). Doctors and nurses, as health professionals, also lacked a comprehensive knowledge of dietary fibre (Whichelow 1988), which is alarming as, according to recent research results, doctors, in particular, are very trusted information sources about health in European countries (Spadaro 2003).

In some other studies, reasonably good consumer knowledge about dietary fibre has been found. American respondents could rate the fibre content of 40 foods to an extent that corresponded quite well to the chemical data about fibre content in the same foods (Sobal and Cassidy 1993). In Ireland, fibre intake from potatoes, vegetables, wholemeal bread and fruits was greater if the respondent's attitude towards fibre was positive (Barker et al. 1995), which indicates a knowledge of the sources of dietary fibre in a diet.

If consumers are unsure about the sources of dietary fibre in the diet, they are unlikely to understand the dietary recommendations in relation to the grams of dietary fibre that they should consume daily and where and how to obtain this amount. Although the recommendations given in grams are basically targeted at food professionals and the recommendations given in food and portion levels (e.g. "you need x pieces of bread per day to obtain sufficient fibre") are targeted at consumers, nevertheless in the public discussion about dietary fibre, e.g. in newspapers, grams are often used, which makes the message ambiguous for consumers. However, the positive image of dietary fibre is an advantage when the aim is to increase its intake at the population level.

Nutritional knowledge is associated with the intake of fat, fruit and vegetables and those in the highest quintile for such knowledge are more likely to meet the consumption recommendations of these components (Wardle et al. 2000). Thus, if consumers do not have sufficient knowledge of the sources of dietary fibre, it may be a barrier to the increase in the intake of dietary fibre in their diet. When the aim is to increase the current intake of dietary fibre, it is essential to clarify consumer perceptions and/or misperceptions of dietary fibre. This knowledge could help to provide suitable and effective information to consumers. A general message about fibre is not as effective as a tailored message, which is based on the individual's own present knowledge, beliefs and attitudes about fibre (Brinberg et al. 2003). In addition, although a general association between dietary fibre intake and its food sources is understood, the specific food sources of fibre may not be recognised (Cashel et al. 2001). Education campaigns alone, however, are not necessarily successful in improving dietary habits. The "five-a-day" campaign in the USA and the UK since the 1990s encourages using a minimum of five portions of vegetables and fruit per day, but it has had a quite small effect on the consumption of fruit and vegetables at national level so far (Lambert et al. 2002). Consumers had difficulty in knowing what foods were defined as fruit and vegetables and what constituted a portion.

Another obstacle to increase the intake of dietary fibre may be the palatability of products rich in dietary fibre. Berg et al. (2003) found that high fibre breakfast cereals and bread were perceived to be healthy but not necessarily palatable among Swedish 11- to 15-year olds. In addition, the palatability of wholesome foods high in fibre is crucial in terms of compliance with a fibre-rich diet (Maier et al. 2000). The food industry could contribute to a health-promoting diet and possibly improve dietary fibre intake by providing tasty high-fibre products, which do not cost more than more refined grain products.

A diet rich in dietary fibre may also cause flatus emissions (Bolin & Stanton 1998), which can be considered annoying. This may be a reason to avoid a diet rich in fibre.

The development of the selection of foods in particular product categories may not have been favourable from the perspective of fibre intake. Consumption of fast food and ready-prepared foods has increased during the past decades all over the world. An Australian study found that the large proportion of energy coming from foods prepared outside the home was associated with a lower intake of dietary fibre (Burns et al. 2002). Of course the quality of these foods varies to a great extent and ready-prepared foods can also be wholesome and health promoting. However, if food habits are shifting towards frequent eating of more processed, ready-prepared foods, the lack of a variety of health-promoting, fibre-rich foods in this category may be an obstacle to increasing fibre intake.

1.2 β-glucan as a source of dietary fibre

β-glucan could be an appropriate dietary fibre alternative to be added into foods. β-glucan was selected because among fibres its health effects are the most extensively documented (e.g. a meta-analysis by Ripsin et al. 1992) and the use of health claims with β-glucan-containing foods is allowed in the USA (FDA 2004), Sweden (Anonymous 2004), Finland (Anonymous 2000) and the UK (Joint Health Claims Initiative 2004).

The β-glucan content of oat and barley varies mostly between 3 and 7% (oats) (Wood & Beer 1998) and between 3 and 11% (barley) (Skendi et al. 2003), making them significant sources of β-glucan in the diet. Food products containing oats or barley are natural sources of β-glucan in the diet. β-glucan can also be added to different foods, either cereal based or others, and in this way expand the selection of possible sources or fibre in the diet. Commercial food products to which β-glucan has been added are, e.g., pasta, oat flakes and cereals and bakery products.

1.2.1 Physical and chemical characteristics of β-glucan

The mixed linkage (1→3)(1→4)-β-D-glucans (β-glucans) in barley and oat are water-soluble, high molecular-weight polysaccharides (Wood 1986). β-glucans result in viscous and shear thinning solutions even at quite low concentrations (Wood and Beer 1998). Therefore, they are suitable alternatives for thickening agents in foods, e.g. beverages (Temelli et al. 2004), sauces, salad dressings and ice creams (Wood 1986). For example, at above a 0.5% concentration, barley β-glucan was found to produce a higher viscosity than pectin at the same concentration (Temelli et al. 2004).

The viscosity of β-glucan depends on the molecular weight, solubility and concentration (Autio 1996, Wood and Beer 1998, Wood et al. 2000). Oat β-glucans generally have a higher molecular weight than barley β-glucan (Wood et al. 1991, Autio 1996, Beer et al. 1997a). This difference between barley and oat β-glucan is relevant to consider in their behaviour in foods (Brennan and Cleary 2005). However, as regards the physiological characteristics of oat and barley β-glucans, they have been reported to have a quite similar efficacy (Delaney et al. 2003, Hallfrisch et al. 2003b).

1.2.2 Health effects of β-glucan

The health effects of oat and barley β-glucans have been studied since the 1970s. The cholesterol-lowering capacity of β-glucan and its ability to balance post-prandial blood glucose and insulin response has been extensively studied. Two meta-analyses by Ripsin et al. (1992) and Brown et al. (1999) have shown that oat β-glucan reduces elevated blood cholesterol levels. In Tables 2 (cholesterol-lowering capacity) and 3 (blood glucose response), a selection of studies conducted since 1990 is presented in more detail. They include studies performed both with oat and barley products, as barley β-glucan has also shown physiological efficacy, although the number of studies conducted with barley is much smaller than that of studies with oat products. In fact, oat and barley β-glucans have been reported to be equally effective (Delaney et al. 2003, Hallfrisch et al. 2003b).

The amount and source of β-glucan in all of these studies has varied, but on average the quantities have been under 10 g of β-glucan per day (Table 2) or per single portion (Table 3). Oat bran and oat bran concentrate have been quite commonly used sources of β-glucan. Most of the studies on the cholesterol-lowering effect have been performed with hypercholesterolemic subjects. In the majority of the studies, the β-glucan preparation has been described only very briefly and the data about its molecular weight are missing in almost every study. It would be of some value to compare the results of different studies in relation to the molecular weight of the β-glucan preparations used.

Table 2. Controlled human studies on the effect of oat or barley β-glucan on blood cholesterol[a] levels since the 1990s.

Study	Study subjects	Study design	β-glucan preparation	Amount of BG	Carrier food	Control diet	Time (weeks)	Change[b] compared to baseline values	Difference[b] compared to control group/control period
OAT β-GLUCAN									
Amundsen et al. 2003	N = 16 (7 F, 9 M), 57±7.9 y, hyper-cholesterolemic	Cross-over	Oat bran concentrate	Oat BG 5.1 g/day	Cereals, bread and muffins, tea cakes, fresh pasta, apple drink	Wheat or rye	3	Decreased, significance not reported	Lower compared to control period
Anderson et al. 1990	N = 12 M, 42–70 y, hyper-cholesterolemic	Cross-over	Oat bran	Soluble fibre 7.4 g/day	Cereals	Corn-flakes	2	Decreased	Lower compared to control period
Anderson et al. 1991	N = 20 M, 38–70 y, hyper-cholesterolemic	Parallel groups	Oat bran	Soluble fibre 13.4 g/day	Hot cereal and oat bran muffins	Wheat bran	3	Decreased; NS change in the control group	
Beer et al. 1995	N = 14 M, 20–28 y, healthy	Cross-over	Oat gum	Oat BG 9 g/day	Instant whip	Placebo whip	2		NS difference compared to control period
Braaten et al. 1994a	N = 19 (10 F, 9 M), 44–64 y, hyper-cholesterolemic	Cross-over	Oat gum	Oat BG 5.8 g/day	Drink (non-carbonated)	Malto-dextrin	4	Decreased	Lower compared to control period

Study	Study subjects	Study design	β-glucan preparation	Amount of BG	Carrier food	Control diet	Time (weeks)	Change[b] compared to baseline values	Difference[b] compared to control group/control period
Davidson et al. 1991	N = 140 M/F, 30–65 y, hyper-cholesterolemic	Parallel groups	Oatmeal or oat bran	Oat BG 1.2–6.0 g/day	Hot cereals, muffins, shakes	Farina	6	Decreased with doses 3.6–6 g BG/day	Lower with 6 g BG in oatmeal and with 3.6–6.0 g BG in oat bran compared to control period
Davy et al. 2002	N = 36 M, 50–75 y, overweight	Parallel groups	Oatmeal and oat bran	Oat BG 5.5 g/day	Oatmeal and oat bran cereals	Wheat cereal	12	Decreased	Time-by-treatment interaction nearly significant
Keenan et al. 1991	N = 145 M, F, 20–70 y, hyper-cholesterolemic	Cross-over	Oat bran	Soluble fibre 6.4 g/day	Cold cereal	Wheat bran	6	Decreased	Decrease greater compared to control group
Kerckhoffs et al. 2003 (Study 1)	N = 48 (27 F, 21 M), ~51.5 y, mildly hyper-cholesterolemic	Parallel groups	A mix of oat bran and oat bran concentrate	Oat BG 5.9 g/day	Bread and cookies	Wheat fibre	4	NS decrease	NS difference compared to control group

Study	Study subjects	Study design	β-glucan preparation	Amount of BG	Carrier food	Control diet	Time (weeks)	Change[b] compared to baseline values	Difference[b] compared to control group/control period
Kerckhoffs et al. 2003 (Study 2)	N = 25 (15 F, 10 M), ~53.5 y, mildly hyper-cholesterolemic		A mix of oat bran and oat bran concentrate	Oat BG 5.0 g/day	Mixed with orange juice	Wheat fibre	2		Lower compared to control period
Kestin et al. 1990	N = 24 M, 29–61 y, mildly hyper-cholesterolemic	Cross-over	Oat bran	Soluble fibre 5.8 g/day	Bread and muffins	Wheat bran	4	NS decrease	Lower compared to control period
Leadbetter et al. 1991	N = 40 (20 F, 20 M) 25–64 y, hyper-cholesterolemic	Cross-over	Oat bran	Oat BG ~1.2–3.6 g/day	Cereals, bread, muffins, hot dishes	No sup-plement	4		NS differences compared to control period
Lovegrove et al. 2000	N = 62 (31 M, 31 F), ~56.6 y, healthy	Parallel groups	Oat bran concentrate	Oat BG 3 g/day	Cereal	Wheat bran 20 g/day	8	NS decrease	NS difference compared to control group
Robitaille et al. 2005	N = 34 F, 22–53 y, overweight	Parallel groups	Oat bran	Oat BG 2.31 g/day	Muffins	No sup-plement	4	NS increase in treatment and control group	NS differences compared to control group
Törrönen et al. 1992	N = 28 M, 25–52 y, hyper-cholesterolemic	Parallel groups	Oat bran concentrate	Oat BG 11.2 g/day	Bread	Wheat	8	NS decrease	NS differences compared to control group

Study	Study subjects	Study design	β-glucan preparation	Amount of BG	Carrier food	Control diet	Time (weeks)	Change[b] compared to baseline values	Difference[b] compared to control group/control period
Uusitupa et al. 1992	N = 36 (16 F, 20 M), ~47.5 y, hyper-cholesterolemic	Parallel groups	Oat bran	Oat BG 10.3 g/day	Juice, yoghurt, porridge and dessert	Wheat bran	8	NS decrease	NS differences compared to control group
Whyte et al. 1992	N = 23 M, 26–60 y, mildly hyper-cholesterolemic	Cross-over	Oat bran	Oat BG 10.3 g	Breakfast cereals	Wheat bran 54 g/day	4	Decreased, significance not reported	Lower compared to control period
Önning et al. 1999	N = 52 M, 52–70 y, moderately hyper-cholesterolemic	Cross-over	Oat bran concentrate	Oat BG 3.8 g/day	Oat milk	Rice milk	5	Decreased	Lower compared to control period
BARLEY β-GLUCAN									
Behall et al. 2004a	N = 25 (18 F, 7 M), ~46.7 y, mildly hyper-cholesterolemic	Cross-over	Barley flakes, barley flour or pearled barley	Barley BG 0, 3 or 6 g/day	Pancakes, cookies, hot cereals, muffins, hot dishes	Wheat or rice	5	Decreased	Lower in medium and high BG groups compared to control period
Behall et al. 2004b	N = 18 M, 28–62 y, moderately hyper-cholesterolemic	Cross-over	Barley flakes, barley flour or pearled barley	Barley BG < 0.4, 3 or 6 g/day	Pancakes, cookies, hot cereals, muffins, hot dishes	Wheat or rice	5	Decreased	Lower in high BG group compared to medium or low BG groups

Study	Study subjects	Study design	β-glucan preparation	Amount of BG	Carrier food	Control diet	Time (weeks)	Change[b] compared to baseline values	Difference[b] compared to control group/control period
Keogh et al. 2003	N = 18 M, 38.8±10.1 y, mildly hyper-cholesterolemic	Cross-over	Enriched barley fibre	Barley BG 9.9 g/day	Bread, waffles, muffins, hot dishes, cakes, cookies	Glucose	4	NS change	NS difference compared to control period
Li et. al. 2003	N = 10 F, 20.4±1.3 y, healthy	Cross-over	Whole grain barley	Barley BG 8.9 g/day	Barley mixed with rice	Rice	4	Decreased	Lower compared to control period
Lupton et al. 1994	N = 79 (43 F, 36 M), 48.2 y, hyper-cholesterolemic	Parallel groups	Barley bran flour or barley oil extract	30 g barley bran flour or 3 g barley oil extract	Beverages (flour) or capsules (oil)	Cellulose 20 g/day	4	Decreased; NS change in control group	
McIntosh et al. 1991	N = 21 M, 30–59 y, mildly hyper-cholesterolemic	Cross-over	Barley bran, barley flakes	Barley BG 8 g/day	Bread, muesli, spaghetti, biscuits	Whole wheat	4	Decreased, significance not reported	Lower compared to control period

BG = β-glucan
NS = non-significant
[a] Serum total cholesterol and/or LDL (low density lipoprotein) cholesterol
[b] Significant change/difference at level $P < 0.05$
Beer et al. 1995: Molecular weight (MW) of BG used was 1 000 000
Kerckhoffs et al. 2003, study 1: Bread: MW < 250 000 55%, MW 250 000–1 000 000 30%
Cookie: MW 250 000–1 000 000 45%, MW > 1 000 000 40%
Kerckhoffs et al. 2003, study 2: MW < 250 000 28%, MW 250 000–1 000 000 49%
Törrönen et al. 1992: MW of BG used 1 500 000

Table 3. Controlled human studies on the effect of oat or barley β-glucan on postprandial blood glucose measurements[a] since the 1990s.

Study	Study subjects	β-glucan preparation	Amount of BG	Carrier food	Control meal	Procedure	Response[b] compared to control load/meal
Braaten et al. 1991	N = 10 (6 F, 4 M), 25±1.8 y, healthy	Oat gum	14.5 g oat gum (78% BG) with 50 g glucose	Gel-like pudding	A drink with 50 g glucose	One load after 12 h fast	Lower response
Braaten et al. 1994b	N = 21 (7 F, 14 M), 38–68 y, healthy and with type 2 diabetes	Oat gum and oat bran	8.8 g BG with porridge meal	Porridge	Wheat farina	One meal after 12 h fast	Lower response in healthy subjects and in type 2 diabetic subjects
Tapola et al. 2005	N = 12 (5 F, 7 M), 66±7 y, type 2 diabetes patients	Oat bran	Oat BG 9.4 g in flour 3.0 g in crisp 4.6 g in flour with glucose	Oat bran flour and oat bran crisps	12.5 g glucose with 250 ml water	One load after 12 h fast	Lower response with oat bran flour with and without glucose; NS difference with oat bran crisp
Tappy et al. 1996	N = 8 (1 F, 7 M), 34–65 y, NIDDM	Oat flour and oat bran	Oat BG 4, 6 or 8.4 g	Breakfast cereal	Continental breakfast (bread, milk, ham, cheese)	One load after 10–12 h fast	Lower response
Wood et al. 1990	N = 9 (5 F, 4 M), 23.6±1.3 y, healthy	Oat gum	14.5 g oat gum (78% BG) with 50 g glucose	Gel-like pudding	A drink with 50 g glucose	One load after an overnight fast	Lower response
Wood et al. 1994 (Study 1)	N = 9 (5 F, 4 M), ~31.5 y, healthy	Oat gum	1.8–7.2 g oat gum with 50 g glucose	Beverage	A drink with 50 g glucose	One load after 12 h fast	NS lower response

Study	Study subjects	β-glucan preparation	Amount of BG	Carrier food	Control meal	Procedure	Response[b] compared to control load/meal
Wood et al. 1994 (Study 2)	N = 11 (5 F, 6 M), ~37.5 y, healthy	Hydrolysed oat gum	7.2 g oat gum with 50 g glucose	Beverage	A drink with 50 g glucose	One load after 12 h fast	NS lower response; the linear component of the treatment effect significant
Wood et al. 1994 (Study 3)	N = 8 (2 F, 6 M), healthy	Instantised oat gum	7.2 g oat gum with 29 g maltodextrin and 21 g glucose	Beverage	A drink with 21 g glucose and 29 g maltodextrin	One load after 12 h fast	NS lower response
Yokoyama et al. 1997	N = 5 (1 F, 4 M), aged 36–60 y, healthy	Enriched barley flour	Barley BG 12 g	Pasta	Wheat pasta	One load after 12 h fast	Lower response

BG = β-glucan
NS = non-significant
[a] Peak glucose response, mean area under glucose curve or plasma glucose
[b] Significant difference at level $P < 0.05$
NIDDM = Non-insulin dependent diabetes mellitus

At the moment, the Food and Drug Administration (FDA) in the USA allows the use of a generic health claim for oat and oat products mentioning the cholesterol-lowering effect of soluble fibre (β-glucan) and the reduction in the risk of coronary heart disease (FDA 2004). In one portion, there has to be at least 0.75 g of β-glucan and from a minimum of four portions it is possible to get 3 g of β-glucan per day. In Sweden, the code of practice concerning health claims also defines the minimum amount of oat β-glucan in one portion (0.75 g) or per day (3 g) (Anonymous 2004). In Finland, the National Food Agency allows a cholesterol-related health claim for oat flakes and oat bran if the product contains at least 5 g β-glucan per 100 g product (Anonymous 2000). In the UK, the Joint Health Claims Initiative allows a generic cholesterol-related claim relating to whole oats, oat bran, rolled oats and whole oat flour if the product contains at least 0.75 g β-glucan per serving, which is a quarter of the suggested daily intake (3 g) (Joint Health Claims Initiative 2004).

Although barley also contains significant amounts of β-glucan and it has been proven to have health effects, these regulations currently cover only β-glucan from oat. It remains to be seen if barley β-glucan will be included in the health-claim regulations in the future.

The viscosity of β-glucan is believed to be extremely important for its physiological efficacy. The size of the β-glucan molecules is an important characteristic of β-glucan, because the viscosity depends on the concentration, solubility and molecular weight of β-glucan (Autio 1996, Wood et al. 2000, Wood 2002). In a study by Ajithkumar et al. (2005), the molecular weight of β-glucan in selected oat cultivars varied between 1 250 000 and 1 780 000. Therefore it could roughly be defined that β-glucan with a molecular weight over 1 000 000 is unprocessed and high, and β-glucan with a molecular weight under 200 000 is strongly degraded and can be regarded as a low molecular weight β-glucan, not contributing strongly to viscosity. β-glucan with a molecular weight between 200 000 and 1 000 000 is degraded but still produces viscosity.

High molecular weight β-glucan produces higher viscosity than low molecular weight β-glucan at the same concentration. High viscosity (Wood et al. 1994) and high molecular weight (Wood et al. 2000) of β-glucan have both proved to be crucial for a decrease in the post-prandial glucose response. Wood (2002) concluded comprehensively that the efficacy of β-glucan is dependent on four features, namely its dose, viscosity, molecular weight and solubility.

The potential physiological mechanisms behind the efficacy of β-glucan are suggested to be its ability to retard the absorption rate of food in the intestine due to increased viscosity, in this way balancing the post-prandial glucose and insulin response (Würsch & Pi-Sunyer 1997, Wood 2000, Jenkins et al. 2004). In addition, Gallaher and Hassel (1995) and Jalili et al. (2000) concluded in their reviews that increased viscosity in the small intestine interferes with cholesterol absorption or re-absorption, in this way affecting the cholesterol balance and synthesis in the body.

Not many human studies have been conducted showing possible adverse effects of a diet rich in β-glucan. Hallfrisch and Behall (2003a) concluded that consumption of oat or barley flour or extract was not related to any particular gastrointestinal symptoms.

1.2.3 β-glucan as an ingredient in processed foods

The food matrix and/or processing of the food in which β-glucan is incorporated, affects its physiological effectiveness. Processing may affect the molecular weight and solubility of β-glucan (Beer et al. 1997b) and therefore influence its physiological efficacy. High molecular weight β-glucan is particularly sensitive to processing. Freezing has not been found to affect the molecular weight of β-glucan (Beer et al. 1997b, , Suortti et al. 2000, Kerckhoffs et al. 2003), but it decreases the solubility of β-glucan (Beer et al. 1997b). On the other hand, heating makes β-glucan more soluble (Bhatty 1992, Jaskari et al. 1995) and enhances its physiological efficacy.

It is essential to consider the influence of food processing on the characteristics of β-glucan, because differences between food products in their cholesterol-lowering effects have been observed. Maier et al. (2000) compared five different ways to provide extra fibre to the diet and they found that an oat bran muffin increased LDL (low-density lipoprotein) cholesterol levels while the other four intervention foods (amaranth muffin, oat bran, oat bran flakes and a variety of oat bran products in the diet) reduced LDL cholesterol as expected. Similarly, a study comparing bread, cookies and a drink as carrier products showed orange juice with β-glucan to lower LDL cholesterol while bread and cookies did not (Kerckhoffs et al. 2003). The baking process of bread decreased the molecular weight of β-glucan but it was not a clear reason for the lack of effect and, in particular, did not explain the ineffectiveness of cookies that contained a relatively high molecular weight β-glucan.

Previously, the effect of processing on the physiological efficacy has not been taken into account in the labelling rules for foods containing β-glucan and the regulations have been based only on the amount of β-glucan in the food. However, currently, in the Swedish health claim code of practice for the food sector (Anonymous 2004) this is taken into consideration by requiring a substantiation of the cholesterol-lowering effect after processing of raw materials rich in β-glucan.

1.2.4 Technological challenges in developing foods with added β-glucan

The viscosity of β-glucan may be problematic regarding the sensory quality of the foods containing β-glucan, but on the other hand it has been found to be important for the physiological effectiveness of β-glucan. The concentration of β-glucan in, e.g., beverages cannot be very high or the increasing viscosity makes the product undrinkable. In addition, the typical slimy texture of β-glucan in the mouth may be unacceptable in some products. Oat has a relatively high fat content compared to other grains and it easily develops a rancid off-flavour in unfavourable conditions (Welch 1995). Products that have a lower viscosity due to a lower molecular weight or a low concentration of β-glucan may have more acceptable sensory characteristics, but may not be physiologically efficacious. In developing foods with a high β-glucan content, this balance between a satisfactory sensory quality and health effects has to be kept in mind (Brennan and Cleary 2005). A food manufacturer should try to minimise the factors that reduce the solubility and molecular weight of β-glucan (Anttila et al. 2004).

Under research conditions, volunteers have rated their liking for test foods containing β-glucan. An oat-based soup with two different flavours was accepted quite well among participants, who consumed it 1–2 times daily for 23 weeks, as only one participant left the trial before the end (Rytter et al. 1996). In a study by Önning et al. (1999), a blackcurrant flavoured oat milk was quite well liked (total liking was 7.2 on a scale of 1–9) among the volunteers and it did not differ from its counterpart (rice beverage with the same flavour) at a single evaluation. The sensory quality of a flavoured oat-based fermented product was acceptable (overall acceptability was 4.4–5.2 on a scale of 0–9) to a semi-trained sensory panel compared to flavoured, commercial yoghurt or non-dairy products (overall acceptability was 5.6–6.0 on a scale of 0–9) (Mårtensson et al. 2001), but this was only a simple taste test, not a long-term study. In a study by Mårtensson et al. (2005), volunteers participating in a trial consumed three servings (200 ml each) of β-glucan containing test products or a dairy-based control product for 5 weeks. The dairy-based product was more preferred than the oat products (the overall impression for the dairy-based product was 7 on a scale of 1–9 and for oat products 4), but the overall impression of one of the oat products improved during the test period from 4 to 6 points on a scale of 1–9. A similar effect was found in the study of Biörklund et al. (2005), where the total impression of the beverage samples with 5 or 10 g of barley or oat β-glucan increased during the test period (not indicated how much). In their study, the beverages with 10 g barley or oat β-glucan were rated lower (3.6 and 3.3 points on a scale of 1–9, respectively) than beverages with 5 g barley or oat β-glucan (5.5 and 5.4 points on a scale of 1–9, respectively), indicating that the increasing concentration of β-glucan impaired the sensory quality of the beverages.

Of course, well-designed consumer studies are certainly needed for defining the actual consumer acceptance of foods with a high β-glucan content, taking into account the various factors affecting the choice of functional foods. The crucial point is the long-term acceptance of these products and their sustained use in order to ensure the regular consumption of the required daily amount of β-glucan for achieving the health effects. A wide selection of different products containing β-glucan could help their versatile and easy use.

1.3 Factors influencing the acceptance of foods with health-related claims

Foods that contain sufficient β-glucan to have a health effect can be considered as functional foods and they could be marketed with health-related claims. The

European Consensus Group in an EU-funded project FUFOSE has presented a commonly used definition for functional foods: "Functional foods are satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease" (Diplock et al. 1999). In Finland, the National Food Agency does not yet have a national definition for functional foods (Anonymous 2002) and for now it accepts the above-mentioned definition.

In an EU-funded PASSCLAIM project (The Process for the Assessment of Scientific Support for Claims on Foods), based on the FUFOSE project, a consensus view of the criteria that should be met for making valid health claims was developed (Aggett et al. 2005). According to the criteria, the following main points should be met for assuring that the health claims made are based on adequate scientific data and are thus valid: The food for which a claim is made must be characterised and the substantiation of the claim must be based on human data. Biologically and methodologically valid markers are to be used if the true endpoint of the benefit cannot be measured and the change in target variable should be statistically significant and biologically meaningful. All of the available data should be taken into account when assessing the validity of a claim.

In this thesis, the concept of functional foods is used in a broad sense, and includes foods that are marketed with health-related claims, whether the health effects have been scientifically proven or not. For example, in most of the studies that have investigated consumer responses towards functional foods, the products have not been tested regarding their actual health effect although they are labelled with health claims in the study situation.

In Finland, there are consumers who question the concept of functional foods and the trend of developing them (Niva et al. 2000). They are suspicious about the general tendency to emphasise the health aspects over the pleasurable and social aspects of foods. On the other hand, there are consumers who are interested in new foods with health effects and the possibility of staying healthy without drugs by using them (Niva et al. 2000). Finnish consumers could be divided into three groups with different attitudes towards functional foods: trustful, unconcerned and doubtful consumers (Niva et al. 2003). Trustful and unconcerned consumers shared positive attitudes towards functional foods whereas trustful and doubtful consumers both considered control and regulation to be important factors.

Consumer expectations towards functional foods may be controversial. Consumers require products that are developed using technology but are still natural and untreated (Niva et al. 2003). In addition to product-specific factors and individual factors, acceptance of these products is influenced by the general discussion of trends in nutrition and food policy, food production and concepts of the healthiness of food (Niva et al. 2003). The general atmosphere is culture dependent and varies from country to country. Dieticians and medical doctors are in important positions regarding their opinions on functional foods. They have a significant influence on their patients and their own personal views on functional foods affect the advice they give to their patients. In a Dutch study, dieticians were somewhat sceptical about the use of functional foods and they were uncertain about the usage, safety, efficacy and target groups of the products (de Jong et al. 2004). Yet, 69% of the respondents thought that functional foods could improve particular body functions and 49% felt that functional foods can play a role in a healthy diet.

Only regular consumption of functional foods confers health benefits on consumers. Regarding functional foods containing β-glucan, the sensory quality of the products and information linked to them are key factors affecting the acceptance of the products. Individual attitudes, motivation factors and some demographic variables such as gender and age are also related to functional food choices. An additional product characteristic, price, is also relevant. In the following sections, these product-specific and individual factors affecting the use of functional foods, particularly foods that are comparable to foods containing β-glucan, is discussed.

1.3.1 Acceptable sensory quality

Pleasantness of food is one of the key factors affecting food choice (Arvola et al. 1999) and its importance dominates health issues (Glanz et al. 1998, Tepper and Trail 1998). Taste determines also the use of nutraceutical products (Cardello and Schutz 2003). Consumers are not willing to compromise between poor taste and health effects (Tuorila and Cardello 2002). They expect an acceptable sensory quality from functional products; in a blind tasting study, Irish consumers selected the juice they preferred the most as being the 'healthiest' sample (Luckow and Delahunty 2004). In a Finnish laddering study, taste and convenience were important reasons for choice of functional foods (Urala and Lähteenmäki 2003). According to a Belgian study, consumers are even less willing to compromise on the taste of functional foods than previously (Verbeke 2006). In addition to taste, the texture of food also significantly affects its liking (Moskowitz and Krieger 1995). Thus, in the development of functional foods the sensory quality of the product is at least equally important as the health effect.

1.3.2 Product information and personal motivation factors

Health claims connected with functional foods influence the acceptance of such foods. In fact, as the health benefit cannot usually be detected in the buying situation or immediately after the consumption of a functional food, information is the only way to communicate about the additional value of the functional product for consumers. Thus, information about the product can enhance the perceived benefit experienced from using the product (Bech-Larsen and Grunert 2003) and can therefore favourably affect its acceptability, for example in terms of willingness to use and buying the product. In their study, the effect of the health claim was positive in all three countries: Denmark, Finland and the USA. In a study by Bower et al. (2003) on fat spreads, information about the nutritional benefit, the name of the product and the price had a significant effect on buying intention. Kihlberg et al. (2005) observed that health information ('Product has a cholesterol-lowering effect') increased the liking of bread among Swedish consumers.

The increasing strength of a health claim does not necessarily have an effect on the perceived benefit of the product and it depends on the familiarity of the functional component (Urala et al. 2003). In their study, Finnish consumers evaluated eight different health related claims, each presented on four strength levels. For example, the level 1 claim was "Product contains plenty of added fibre" and the level 4 claim was "The added fibre in the product prevents cancer". If the functional component was familiar, the increasing strength of the claim did not increase the perceived benefit but if the component was less familiar, the perceived advantage improved with the increasing strength of the claim. According to Bech-Larsen et al. (2001), 71% of Danish consumers, 73% of Finns and 53% of Americans consider themselves to be aware of the health effect of fibre. Thus, fibre can be regarded as quite a familiar component for consumers and therefore a less strong health claim could be sufficient for informing consumers about the health effects of fibre-rich foods. However, β-glucan is probably not as familiar a concept as fibre in general.

The efficacy of product information is not constant in all cases and for all consumers. Consumers' attitudes and personal needs define what information is noted and if and how these new beliefs are incorporated into consumers' knowledge systems (Lähteenmäki 2003). The type of consumers' nutrition knowledge has also been shown to have an effect on intended consumption of a functional food (Wansink et al. 2005). Those who had both attribute-related knowledge (e.g. 'This food contains β-glucan') and consequence-related knowledge (e.g. 'β-glucan reduces your risk of coronary heart disease') of functional foods were more willing to consume these products compared to those with only one type of information.

Consumers with health problems have been found to seek specific nutrition information that has relevance to them (Bhaskaran and Hardley 2002). For example, those who had high cholesterol levels were looking for cholesterol-free foods. An ill family member had a positive effect on the likelihood of acceptance of functional foods (Verbeke 2005). Information about the fibre content of a food was relevant for the elderly who were concerned about their fibre intake and thus it increased their purchase intent, contrary to younger consumers (Tuorila et al. 1998). The perceived reward from using functional foods is the best predictor for willingness to use such foods (Urala and Lähteenmäki 2004).

1.3.3 The role of carrier product

The nutritional quality of the carrier product defines more how consumers perceive the healthiness of functional foods than the health claim attached to the products (Bech-Larsen and Grunert 2003). Functional foods are not perceived only as functional foods but primarily to be members of particular product categories (Urala and Lähteenmäki 2003). In accordance with this, a chocolate bar labelled with a health claim was not classified as a functional food but as a member of the chocolate product group in focus group discussions in Finland (Di Monaco et al. 2005). Therefore the use of functional foods cannot be disconnected from their 'traditional' counterparts, and the existing health image of the carrier product group has an effect on consumer reactions towards the modified product. In a Finnish study, butter with a health claim about the positive health effect of conjugated linoleic acid was not accepted because butter itself has a negative health image in Finland (Lähteenmäki 2000). Because of this, a positive message attached to butter was regarded as false and irrelevant.

In addition to this, a very healthy product does not necessarily benefit from the addition of a functional component. If a product is perceived to be healthy as such, the added functionality does not necessarily make the product healthier in consumers' minds compared to some other products (Bech-Larsen and Grunert 2003). However, enriching a product with a compound already present in the product makes it acceptable to consumers. Danish consumers were most positive about functional foods that were enriched with a compound already existing in the product at lower concentration, e.g. enrichment of oat flakes with extra β-glucan (Poulsen 1999).

A discrepancy may exist between the opinions and views of consumers, food technologists, nutritionists and marketing professionals as regards successful and attractive carrier products and functional food concepts. Van Kleef et al. (2002) tested 300 mini-concepts with a varying carrier product, functional ingredient and health claim using 50 Dutch consumers by presenting verbal and visual information of the concepts. In addition, they interviewed 38 experts on food technology, nutrition or marketing. Comparison of the results showed that the experts could improve their understanding concerning consumers' views, nutritionists in particular, as the views of consumers and experts differed. For example, consumers did not find pills to be as attractive carriers for functional ingredients as did marketing professionals and food technologists. Consumers also found some carrier products to be more attractive than the experts, such as soups, chocolate, chewing gum and ice cream.

1.3.4 The effect of age and gender on the acceptance of functional foods

In some studies, women and elderly consumers have been shown to have higher potential as users of functional foods. Finnish women were more willing to use functional products than men, except cholesterol-lowering spreads (Niva et al. 2003). In Finland, the proportion of users of plant stanol ester margarine has been found to increase with age (Anttolainen et al. 2001). The elderly and women had a more positive attitude towards functional foods in Denmark (Poulsen 1999). However, opposing results exist also; Verbeke (2005) did not observe a gender effect in the acceptance of functional foods in Belgium and de Jong et al. (2003) found no difference between Dutch women and men in the use of cholesterol-lowering margarine. Thus, it seems that some of these so-called traditional demographic variables are not the best predictors for the use of functional foods in general, but they may be suitable for single products.

1.3.5 Price

Obviously the price of functional foods has an effect on their acceptance, as most of the consumers have restricted financial resources to use. Usually functional foods are more expensive than their traditional counterparts. Ollila et al. (2004) studied the effect of price in a representative sample of the Finnish population, observing it to have a key role in buying decisions of functional foods. Di Monaco et al. (2005) found that increasing the price reduced the likelihood of buying both for regular chocolate bars and chocolate bars with a health claim in Finland. Thus, the effect of increasing price was similar for both regular and functional products. Poulsen (1999) concluded that a positive attitude towards enriched products increased the willingness to pay more for these products, but he also mentioned that the role of price was not totally clear among Danish consumers. Among Dutch dieticians, 89% of the respondents thought that functional foods are expensive (de Jong et al. 2004). Their personal opinions may have a significant influence on the advice they give to their patients.

1.3.6 Aims of the study

As the intake of dietary fibre in general is below the recommendations, new ways to improve it should be explored. The general nutrition education about increasing the use of traditional sources of fibre has not been effective enough. The changing food consumption patterns indicate that new ways of including foods rich in dietary fibre in the diet would also be needed (Figure 2). These products should have an acceptable product quality and high consumer acceptance. The general aim of this thesis was to investigate whether providing foods enriched with β-glucan would produce a feasible strategy for improving consumers' dietary fibre intake (Figure 2).

The more detailed objectives were to study:

- how Finnish consumers perceive the role of fibre in a healthy diet and explore possible barriers to increasing fibre intake (I)

- how added β-glucan influences the perceived product quality, e.g. the sensory characteristics of two prototype foods, namely a beverage and a ready-to-eat frozen soup (II and III)

- consumer acceptability of β-glucan-containing beverage and ready-to-eat frozen soup prototypes and the role of health related claims in three countries differing in their food culture and views on healthy eating (IV)

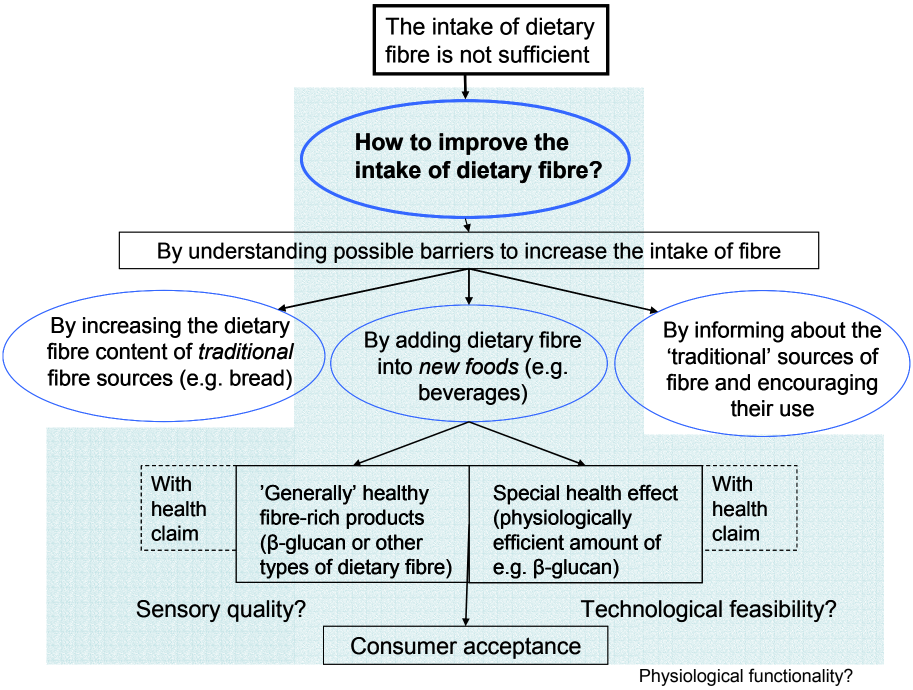

Figure 2. Different means to improve the intake of dietary fibre and the aims of the present study (shaded).

2. Materials and methods

The samples and experimental protocols are described only generally in this section. For more detailed information see the original Publications I–IV.

2.1 General description of the studies

Study I examined how Finnish consumers perceive the role of fibre in a healthy diet. Studies II and III concentrated on the sensory quality of β-glucan-containing foods. Two prototype foods were selected for the studies, namely beverage and ready-made frozen soup. The aim was to examine the effect of different oat (II and III) and barley (III) β-glucan preparations on the sensory characteristics and viscosity of a beverage prototype (II) and a ready-made soup prototype (III) and the influence of freezing on these parameters in soups (III). We also reflected on the sensory results as regards the chemical and physical characteristics of β-glucan. Study IV investigated consumer reactions towards beverages and ready-made frozen soups containing β-glucan in Finland, France and Sweden with the objective of describing the key factors for willingness to use these products. The three countries were selected because they were thought to represent different food cultures and to display variations in consumer views regarding the definitions of healthy eating (Margetts et al. 1997), the perceived benefits of healthy eating (Zunft et al. 1997) and the perceived need to alter eating habits (Kearney et al. 1997).

A beverage and a soup were chosen as examples of foods that are not naturally significant sources of dietary fibre but where β-glucan could be added. Although it may be challenging technologically to add a viscous fibre into beverages, beverages as vehicles for functional components are very interesting, because their consumption has increased during the past decades in Finland (Lahti-Koski and Siren 2004) and the consumption of portable beverages worldwide is increasing (Sloan 2004). According to Menrad (2003), it is also an important product category within functional foods. A ready-to-eat frozen soup is a potential product because of the increasing interest in ready-to-eat foods (Sloan 2005), and because consumers regard it as an interesting carrier product (van Kleef et al. 2002).

Table 4 presents in detail the aims, samples and participants.

Table 4. Aim of the studies and the samples and the participants.

Study	Aim	Carrier food	Molecular weight of β-glucan	Concentrations used	Reference sample	Participants
I	To describe Finnish consumers' perceptions of dietary fibre in a healthy diet.	-	-	-	-	Consumers: N = 125 (F 51%, M 49%, mean age 42 years)
II	To study the effect of different oat β-glucan fractions on the sensory quality and viscosity of a beverage prototype.	Orange beverage	BG1: 2 000 000 BG2: 2 000 000 BG3: 160 000 BG4: 60 000	BG1 and BG2: 0.25%, 0.5% and 1.0% BG3 and BG4: 0.5%, 1.0% and 2%	Orange beverage thickened with 1.3% CMC	Trained sensory panel: N = 9–10
III	To examine the effect of different oat and barley β-glucan fractions on the sensory quality and viscosity of a ready-made soup and whether freezing affects these parameters.	Roasted bell-pepper soup	Oat 1: 2 000 000 Oat 2: 200 000 Barley: 40 000	Oat 1: 0.25%, 0.5% and 1.0% Oat 2 and Barley: 0.5%, 1.0% and 2%	Soup thickened with 0.8% modified starch	Trained sensory panel: N = 10
IV	To investigate which factors influence consumers' willingness to use a ready-made soup and beverage with oat β-glucan in three countries.	Apple-pear beverage Frozen ready-made shrimp-dill soup	Beverage: preparation 200 000 (in beverage 80–100 000) Soup: 80 000	1.0%	Apple-pear beverage and shrimp-dill soup without β-glucan	Trained sensory panel: N = 11 Consumers: N = 1157 in total (F 57%, M 43%); Finland N = 353; France N = 410; Sweden N = 394, mainly over 40 years

CMC = Carboxymethyl cellulose
F = female
M = male

2.2 Samples (Studies II–III and IV)

2.2.1 β-glucan preparations used in Studies II–IV

The β-glucan preparations used in Studies II–IV varied in their molecular weight between 40 000 and 2 000 000 (Table 3). The preparations were not identical in any of the studies, but, for example, preparation BG2 in Study II and Oat 1 in Study III were quite similar, oat-bran-type preparations, and preparation BG3 in Study II and Oat 2 in Study III were also quite similar, more processed preparations. Due to practical reasons (e.g. timetable of the studies), it was not possible to use the same preparations in each study, as the product is quite sensitive and not suitable for storing over a long time.

The suppliers of the preparations were the same in each study. The name of the company supplying the dry milled oat bran in Studies II and III changed between Studies II (Avena Oat Ingredients) and III (Finn Cereal), but it actually is the same company.

2.2.2 Beverage and soup samples

The samples used in Studies II–III and IV were either soups or beverages. Beverages were either orange (II) or apple-pear (IV) juice and soups were either roasted bell-pepper (III) or shrimp-dill (IV). In the orange beverages (II), four oat β-glucan preparations were used as thickeners and in the reference sample the thickener used was CMC (carboxymethyl cellulose). The β-glucan preparations were all added at three concentrations and the reference sample thickener at one concentration level. The samples were evaluated at room temperature (~20°C).

The selection of the concentration levels of the beverage samples was based on preliminary tests with the preparations. Because the viscosity-forming properties of the preparations were quite different, the BG1 and BG2 preparations being different from the BG3 and BG4 preparations, compromises had to be made, as the target was also to form an equivalent concentration series of each preparation to make the comparisons between them possible. In addition, the FDA regulation concerning the minimum amount of β-glucan per portion (0.75 g) or 3 g per day for using a cholesterol-related health claim was considered. Basically, the objective was to put as much β-glucan as possible into the product.

In the roasted bell-pepper soup (III), two oat and one barley β-glucan preparations were added as thickeners at three concentration levels and the reference sample was thickened with modified starch at one concentration level. The samples were evaluated at +60°C. In both Studies II and III, the samples were evaluated at the sensory laboratory of VTT Biotechnology. The apple-pear beverage and the shrimp-dill soup samples in the consumer study (IV) either did not contain β-glucan or they contained β-glucan at one concentration level. The reference soup was thickened with maize starch. Consumers were advised to taste the beverage samples at refrigerator temperature and the soup samples after heating according to instructions (at circa +60–80°C) at home. For more detailed information about the samples, see Table 4 or the original publications.

The carrier foods used in Studies II–IV were the same, beverages and soups, although different flavours were used. In Study II, orange flavour was chosen, because it is a relatively familiar and neutral flavour and thus it did not excessively dominate the evaluation of the beverage samples. In Study III, the tomato-based roasted bell-pepper soup was considered suitable; as the β-glucan preparations were added to the soup base separately at VTT Biotechnology, for practicality, a homogenous soup was convenient. In Study IV, the apple-pear beverage sample and shrimp-dill soup sample were prepared on an industrial scale and the selection of the flavours was based on practicalities. In addition, these samples were used in clinical trials (not conducted by us), and the selection was also made from this point of view.

In Study IV, the use frequency of five different beverage types and five different soup types was rated in each country for screening the use frequency of the product categories (beverages and soups) in the study population. Some differences between countries existed between different types of beverages and soups, but, in general, respondents were users of the target products.

2.3 Participants

The participants were trained sensory panellists from VTT Biotechnology (II, III, IV) or consumers (I, IV). The trained sensory panellists in Studies II, III and IV created the vocabulary for evaluation of the samples and conducted a descriptive analysis. Panellists were staff of VTT Biotechnology and all were permanent members of a trained in-house panel with experience in sensory evaluation.

The panellists who developed the sensory vocabulary for the descriptive analysis of the samples (II, III, IV) were long-term (several years or more) members of the trained in-house panel at VTT Biotechnology. In Studies II–IV, the vocabularies for beverages and soups were developed by the same three or four panellists, although the fourth or fifth panellist was different for practical reasons. These panellists were experienced with the profiling of different types of foods, including beverages. The members of the whole sensory panel used in Studies II–IV completed and passed basic taste tests before joining the panel, and they also received education about the basic elements of sensory evaluation routines and methods. The new panel members participate in the evaluations as extra assessors whose ratings are omitted from the results. After three training sessions with a certain method (e.g. descriptive analysis) and fulfilling the criteria that the results of the particular panellist are within a prescribed range from the panel mean for 80% of the attributes in the descriptive analysis, they are included as full panel members. After this, in each project, the panel performance is monitored and further training and feedback are given.

The perceived role of fibre in a healthy diet was studied among Finnish consumers (I). A convenience sample of respondents was recruited from libraries, indoor swimming pools and shopping centres, places that are accessed by heterogeneous individuals. In Study IV, consumers in Finland, France and Sweden rated the liking and beneficiality of the samples and willingness to use and pay for them and filled in a background questionnaire. In all countries, the respondents were users of the target products. In this study, the Finnish convenience sample of consumers was recruited from shopping malls, sports centres, fire stations and from VTT (Technical Research Centre of Finland), because these locations are visited by individuals with different backgrounds. In France and Sweden, volunteers were recruited from consumer panels. In France, the collection of the data was carried out in three regions (the west and southeast France and in Paris) to ensure a better representation of French consumers. The consumers were selected from a consumer database that was organised by a French food research institute. Unfortunately there is a lack of detail about the panel as a whole. In Sweden, the entire consumer panel comprises approximately 2300 members of whom 70% are women and 30% men, and who are aged between 18 and 75 years. The panellists are from southern Sweden, including both families with children and single households. The panel was recruited in the beginning of the year 2002 by advertising in local newspapers.

The target age group of the respondents in our study was 40 years or over, because they are more likely to be interested in these products than younger consumers, who do not need to think urgently about disease risk factors related to ageing. In Table 4 and in original publications I–IV, the participants are described in more detail.

2.4 Procedure and methods

In Study I, a semi-structured interview was used as the study method. Questions concerned the respondent's perceptions of a healthy diet, the function, sources and required amount of dietary fibre, information about dietary fibre and the use of bread (bread-related results were not reported in Study I). The respondents did not know, prior to the interview, that the actual theme of interest would be dietary fibre as they were told that the theme was health in general. Background information on socio-demographic factors and the health condition of the participants was collected and respondents also completed a fibre intake test (The Finnish Bread Information 1999) for assessing dietary fibre intake (Study I, Appendix 1). The fibre test (The Finnish Bread Information 1999) used in Study I is a quick, self-administered tool for estimation of dietary fibre intake. It is possible to roughly estimate respondents' intake of fibre with the test and it can be used for dividing respondents into different fibre intake- categories, or to monitor changes in respondent's fibre intake. Each point in the test approximately equals the amount of food product that contains 1 g of fibre, but the test is too rough for direct conversion of points into grams of fibre. However, the classification of respondents into different categories according to their self-estimated fibre intake was thought to be appropriate. The fibre test has been validated with food diaries (Wegelius, unpublished data).

In Studies II–IV, the sensory evaluation of the samples was conducted with generic descriptive analysis (Lawless and Heymann 1998). The vocabulary was developed in one session in each study and a panel trained in three (II) or two (III) or one (IV) training sessions, the length of each session being about 30 min. The actual evaluations were conducted in eight (II) or twelve (III) or two (IV) sessions (including the replicate sessions) with blind-coded samples in the sensory evaluation laboratory at VTT Biotechnology, using a computerised data-gathering system (Compusense Inc.). Detailed instructions to the panellists for conducting the evaluations were used in each evaluation session. They included instructions on how to conduct the evaluation of the samples for each attribute. As an example, in Study II, the attribute "Thickness of the beverage in the mouth" was to be evaluated in the following way: "Evaluate the thickness of the beverage in the mouth by moving it around with your tongue. An example of a 'not at all thick' beverage is water or juice, and an example of an 'extremely thick' beverage is syrup or a thick fool."

Constant rate measurement of viscosity as a function of shear rate was performed from the same samples evaluated by the sensory panel (II and III) with a StressTech rheometer at shear rates 16.4–157 s^{-1} at +20°C (II) or at +60°C (III).

In Study IV, consumers in Finland, France and Sweden evaluated their liking, perceived beneficiality and willingness to use the beverage or soup samples and how much they were willing to pay for them before and after tasting. They also completed a background questionnaire containing questions about demographic variables, general liking and use frequency of different soups and beverages, and health-related and attitude questions (attitude results were not reported in Study IV).

2.5 Data analysis

The data were analysed using the standard statistical procedures as described individually in Studies I–IV.

In Study I about consumer perceptions of dietary fibre, the content of the responses were first analysed and preliminarily categorised by the interviewer, after which all the authors jointly discussed the categorisation and some changes were then made before making the final categorisation. The frequency distributions were tested using the χ^2-test. The consumer data of Study IV were analysed using General Linear Model (GLM) Repeated Measures analysis to test the differences between samples in liking, perceived beneficiality and willingness to use them before and after tasting, and whether there would be differences between countries. In addition, the willingness to use samples among different age groups and by gender before and after tasting was tested using GLM Repeated Measures analysis. If significant differences were found in GLM Repeated Measures Analyses, further analyses were performed either using Tukey's test or Paired Samples T-test. Pearson Correlation, two-tailed, was used in correlation analyses.

The effect of β-glucan source and concentration and freezing (only in Study III) on the differences between samples in sensory attributes was tested with ANOVA (Analysis of variance) in Studies II and III. In Study III, the analyses were run in several steps due to incomplete data. The data were incomplete because the concentration series of different samples varied (Oat 1: 0.25, 0.5 and 1%; Oat 2 and Barley: 0.5, 1 and 2%), and therefore it was not recommended to include them in the same analysis. If significant differences were found in ANOVA, the differences between samples were further tested with Tukey's test ($p < 0.05$). In Study III, the effect of freezing on the instrumental viscosity at a shear rate of 50 s^{-1} was analysed using the paired samples T-test. The relationships between sensory attributes and the instrumental measurements (viscosity and molecular weight) were analysed with correlation tests in Studies II and III. In Study IV, the differences between the sensory characteristics of the two beverage/soup samples were tested with ANOVA.

SPSS software (SPSS Inc.) was used in all statistical tests.

3. Results

3.1 Consumer perceptions of a healthy diet and dietary fibre in it (I)

3.1.1 Defining a healthy diet

In Study I, which concerned consumer perceptions of a healthy diet and dietary fibre in it, the majority, 62%, of the respondents, defined their own diet as being healthy. The essential elements of a healthy diet, such as ‘vegetables’ (58%), ‘low in fat’ (34%), ‘fruit and berries (22%)’ and ‘variety (20%)’, were mentioned frequently. Thus, in theory the elements of a health-promoting diet are known. Only 5% of the respondents mentioned fibre as an element of a healthy diet, which means that dietary fibre was not spontaneously considered to be part of a healthy diet.

3.1.2 Intake and sources of fibre

We asked the respondents’ opinion of their fibre intake. The majority of the respondents (almost 75%) considered the fibre content of their diet to be ‘adequate’ or ‘possibly adequate’. About one-fifth thought that it was ‘inadequate’ or ‘maybe inadequate’, and 6% could not estimate the amount of fibre in their diet. We then compared these results with the results from a fibre intake test. Among those who thought that their fibre intake was sufficient, about 40% actually had an inadequate intake of fibre and about 60% adequate. Noteworthy, about two-thirds of the respondents in the lowest fibre intake group incorrectly considered their fibre intake as being adequate/maybe adequate. The rest of them correctly estimated the intake as being inadequate/maybe inadequate.

The respondents stated that bread, vegetables and fruit were the best sources of fibre in their diet. Respectively, based on the fibre test (I: Appendix) results, bread (62.3% of the total fibre intake), vegetables (10.2%) and fruit and berries (8.4%) were the most important sources of dietary fibre (I: Fig. 1). The role of vegetables, fruit and berries as fibre sources was slightly overestimated in the interview compared to their actual proportions in the fibre test.

The results were completely different when the respondents were asked to estimate the *amount* of fibre that they should consume daily. Only a quarter of the respondents thought they might know the amount, the estimations varying between ‘800 mg’ and two-thirds of the entire food intake. Consumers could not evaluate their fibre intake in the manner that is commonly used by nutritionists as a base for dietary recommendations given at food and portion level.

Based on the results from the fibre test, about half of the respondents could be classified as having an adequate intake of fibre. Altogether about one-third had insufficient or poor intake of fibre. Although the fibre intake of men was, on average, higher than that of women, there was a trend indicating the presence of more men than women in the lowest fibre intake group, but the difference was not statistically significant.

3.1.3 Perceptions of the role of dietary fibre in health

When the respondents were asked to spontaneously describe the key elements of a healthy diet, only 5% mentioned ‘fibre’ and 10% ‘bread’ on this occasion. On the other hand, 68% of the respondents considered fibre as very important for their health when this was specially asked. There were no differences between age groups regarding the perceived importance of fibre for health.

Respondents were then asked to describe why a sufficient intake of fibre was important for them. ‘Bowel function’ (mentioned by 39% of the respondents) and ‘general well-being’ (29%) were most often mentioned in response to this item. Dietary fibre was often defined by its functions: 'related to bowel/stomach function' (24%), 'related to digestion' (23%) and 'makes one feel full, decreases appetite' (12%) being the most frequent comments. Apart from these functional definitions, fibre was often defined by food items that the respondent thought to contain fibre. Vegetables (42%), cereals (33%), fruit (27%), bread (25%) and porridge (19%) were most often mentioned here. Thus, respondents seemed to be quite well informed about the sources of fibre in the diet as compared to the actual sources estimated with the fibre test (I: Fig. 1).

3.2 The effect of β-glucan on the sensory characteristics of beverages and soups (II and III)

3.2.1 Sensory profiles of the samples

Beverages and soups containing high molecular weight β-glucan (molecular weight 2 000 000) were thicker, slimier and more extensible compared to beverages and soups containing low molecular weight β-glucan (molecular weight 40 000–200 000) at the same concentration. In particular, the thickness and extensibility of beverages (II: Figs. 3 & 4) and the thickness, extensibility and sliminess of soups (III: Figs. 2–4) varied to a great extent between β-glucan types with different molecular weights.

Additionally, the changes as a function of concentration of β-glucan in the texture attribute intensities, such as thickness, sliminess and extensibility, were dissimilar in different preparations. In beverages, the high molecular weight β-glucans were more effective thickeners than low molecular weight β-glucans as a function of concentration. In soups, barley β-glucan increased sensory thickness only at concentrations ≥ 1% (III: Fig. 3) while oat β-glucan thickened the soup at lower levels (III: Fig. 3).

As the result of the β-glucan concentration in thicker beverages and soups, some flavour attributes were suppressed. Additionally, in Study III barley β-glucan seemed to modify taste attributes differently than oat β-glucan; the deterioration of flavours with increasing β-glucan concentration was weaker in soups containing barley β-glucan (III: Figs. 5–8).

Both in beverages and in soups, the maximum concentration of β-glucan was 0.5% for the high molecular weight preparations because above that concentration the beverages and soups became too thick. With the lower molecular weight preparations it was possible to add 2% β-glucan to beverages and soups and still have a feasible thickness.

The sensory profiles of the beverages and soups in Study IV showed that the beverage with β-glucan had a more intense oat flavour and weaker intensity of fruit aroma, total flavour intensity and sourness (IV: Fig. 2). The rancid off-flavour in the β-glucan beverage detected by the sensory panel was notable. The texture of the β-glucan beverage was thicker, more extensible, grainier and slimier than the beverage without β-glucan (IV: Fig. 2). Despite the off-flavour detected in the β-glucan beverage, the microbiological quality of the beverage was normal, and the same samples were used in a clinical study conducted elsewhere. It was then decided to use them in the consumer tests also.

The soup with β-glucan had a less intense orange colour, the freshness of the aroma, the intensity of the shrimp aroma, the shrimp flavour, the dill flavour, the freshness of the flavour, the saltiness and the total flavour intensity than the soup without β-glucan (IV: Fig. 3). The intensity of the grain flavour and the possible off-flavour were more intense in the β-glucan soup compared to the soup without, but the off-flavour was much weaker than in the β-glucan beverage.

3.2.2 The effect of freezing (III)

Freezing the soups did not change their sensory quality (III), in practice, because the only difference found was a 0.5 point decrease on a scale of 0–10 in powderiness of the mouthfeel. However, freezing had a lowering effect on instrumentally measured viscosity, reducing it by about 30%, but this change was not observed in the sensory evaluation of the samples. Molecular weight did not notably change during freezing treatment.

3.2.3 The link between instrumental viscosity and sensory characteristics (II and III)

The correlation between instrumentally measured viscosity and sensory thickness was good. In beverages, the correlations were between 0.63 and 0.78 at shear rates of 26–100/s and in soups the correlation was 0.77 at a shear rate of 50/s. Many flavour characteristics correlated negatively with the viscosity of beverages and soups; in beverages, these attributes were sourness, intensity of orange aroma and total flavour intensity and, in soups, the intensity of tomato flavour, saltiness, sharpness and total flavour intensity.

3.3 Consumers' willingness to use beverages and soups containing oat β-glucan (IV)

For each beverage and soup sample, the respondents rated their liking, perceived beneficiality and willingness to use the particular sample *before* and *after* tasting. These three variables were inter-dependent as the correlations between the variables varied between 0.65 and 0.84 (beverages) and in soups between 0.58 and 0.82 (analysed all countries together, after tasting). Despite this, the results are reported separately as the variation in the variables was different as the correlations were not completely close to 1.0.

Liking for the products strongly determined the willingness to use them. Particularly in beverages containing β-glucan, liking, and thereby willingness to use them, decreased notably after tasting (IV: Figs. 4 & 6). Sensory evaluation of the samples by a trained panel showed that the beverage with β-glucan had a significant rancid off-flavour (IV: Fig. 2). The expected liking and willingness to use and particularly the perceived beneficiality were higher in β-glucan beverages with a health claim (IV: Fig. 5). After tasting, liking, perceived beneficiality and willingness to use decreased in beverages with β-glucan. Despite this decline, the β-glucan beverage with a health claim (either cholesterol or glucose related) was still perceived to be more beneficial than the β-glucan beverage without a health claim.

In soup samples, the presence of the health claim did not have a notable effect on liking before or after tasting but it increased the perceived beneficiality (before and after tasting) and willingness to use (only before tasting) compared to the other two samples (IV: Figs. 7–9). However, the differences between samples were very small on a scale of 1–7, especially in the glucose claim subgroup. The soups with β-glucan had much the same level of acceptance as the soup without β-glucan.

3.3.1 Differences between countries

The *perceived beneficiality* of beverages and soups was rated similarly in Finland, France and Sweden. In liking and in willingness to use beverages and soups, there were some differences between countries. *Liking* of beverages without β-glucan in the cholesterol claim subgroup increased in Finland and Sweden after tasting but did not change in France. In soups, in the cholesterol claim subgroup in Sweden the sample without β-glucan was the best liked after tasting, while in Finland and in France all the samples were almost equally liked. The *willingness to use* beverages in the glucose claim subgroup differed between the three countries; after tasting, the willingness to use beverages with β-glucan decreased more steeply in France than in Finland and Sweden. In soups, in the cholesterol claim subgroup, Swedish consumers were most willing to use the sample without β-glucan after tasting while in Finland and in France all the samples were equally rated after tasting. However, these differences between countries were not very large.

3.3.2 The effect of age, gender and health motivation on willingness to use

Only the beverage group in Sweden showed an age effect on willingness to use. The youngest consumer group (≤ 48 years) was least willing to use the beverage with the health claim compared to the two oldest age groups.

No considerable differences were found between women's and men's willingness to use beverages and soups with health claims, despite some very small statistically significant differences and weak interactions between rating time, sample and gender, and rating time, country and gender.

A personal need to pay attention to blood cholesterol and glucose levels correlated weakly but significantly with an increased willingness to use β-glucan *beverages* with cholesterol/glucose-related health claims (correlation coefficients 0.15–0.30), the correlations being higher after tasting. No such effect was found in the soup group.

3.3.3 Willingness to pay for beverages and soups with health claims

The respondents were asked what would be the maximum prices they would be willing to pay for trying and regularly using each product. *Before tasting,* consumers were willing to pay the highest price for beverages (€1.20/portion;

250 ml) and soups (€2.35–2.42/portion) with β-glucan and a health claim. *After tasting*, the price that respondents were willing to pay for a beverage with a health claim dropped dramatically, by about 22–27%. Also, the prices for beverages with β-glucan but without a claim dropped by about 18–24%. In soups with β-glucan, the prices decreased by about 15% after tasting. The prices respondents were willing to pay for beverages and soups without β-glucan fell also, but slightly, between 4% and 10%. It seems that respondents were not willing to pay more for products with health claims.

Willingness to use a product correlated significantly with willingness to pay for trying or regularly buying the beverages and soup, the correlation coefficients varying between 0.34 and 0.52. Good correlations were obtained between willingness to pay to try a product and to regularly buy a product. In beverages, the correlations varied between 0.70 and 0.75 and in soups between 0.78 and 0.80.

4. Discussion

4.1 Methodological considerations

The semi-structured interview method was chosen in Study I because we wanted to gather information about consumers' opinions and views on health-promoting diet and fibre in their own language, and to understand their perceptions as a whole, without prior strong hypotheses (Eskola and Suoranta 2000). The structure helps in keeping the interviews similar every time; however, the method is flexible enough to take into account differences between respondents' response styles. The recorded interviews increased the reliability of the results as it was possible to check the notes written during the interview afterwards (Breakwell 2000). Content analysis and categorisation of the results made it possible to better find and describe larger issues in the data. This increases the information content and the meaningfulness of the data (Eskola and Suoranta 2000).

The content analysis and preliminary categorisation of the results were done by the interviewer (one of the investigators), after which all the investigators jointly discussed the categorisation and some changes were then made. In an optimal situation, the content analysis and categorisation of the results would have been made by several people independently in order to avoid bias, which may occur if difficulties in interpretation exist.

The size of the study population in Study I, 125 volunteers, was thought to be sufficient, as the same topics came up repeatedly, and according to a text book by Eskola & Suoranta (2000), it means that the data begin to reach saturation point. Men and women of different age groups were represented, although the study population had a slightly higher level of education than the Finnish population on average. In addition, Huotilainen et al. (2005) describe that the minimum number of participants in a qualitative interview study should be 10–50. A qualitative study is useful in describing and understanding a phenomenon (Eskola and Suoranta 2000) but the quantitative significance of the phenomenon in a particular population needs to be further studied with quantitative methods.

Because respondents did not know beforehand that their opinions on dietary fibre was what was of actual interest, the method improved the likelihood of spontaneous reactions towards fibre, which would help in capturing realistic opinions of the topic. On the other hand, because the topics concerned health and diet, there may be a tendency to please the interviewer (Norenzayan & Schwarz 1999) by giving socially acceptable opinions on these matters, thus positively biasing the opinions on fibre and a health-promoting diet. In addition, as participation was voluntary, it is most likely that those who are willing to participate in these kinds of studies differ from those who are not willing. The participants may be more interested in food and health than the non-participants and also have a better knowledge of these matters. However, only about 20% of all contacted volunteers refused to take part thus indicating that there was not an extensive selectiveness bias in the data.

The fibre test (The Finnish Bread Information 1999) used in Study I may cause a slight overestimation of fibre intake because all choices increase fibre intake and the social acceptability of a high-fibre diet may influence the reported fibre intakes. However, in our study, the points gained from each selected food were not shown to the respondents while they were completing the questionnaire. In our study, the mean fibre intake points were 33 for men and 27 for women. The average fibre intake measured with 48-h dietary recall is 21.8 g/day for men and 18.5 g/day for women in Finland (Männistö et al. 2003). Thus, the absolute points in our study were higher than measured fibre intake in an average Finnish population, which shows that converting the points directly into grams would not be valid. However, the classification of respondents into different categories according to their self-estimated fibre intake appeared to be appropriate (Wegelius, unpublished data).

The descriptive analysis method used in Studies II–IV is suitable for defining the sensory characteristics of the product in detail and it produces objective information about the sensory attributes (Lawless and Heymann 1998). The reliability of the results can be improved by using replicate evaluation sessions and by training the panel, as was done in these studies. In addition, the use of warm-up samples in Studies II–III increase panellist reliability (Plemmons & Resurreccion 1998) and the scales used by panellists were adjusted with these reference sample ratings. The results obtained by the descriptive method are relative, however, and comparisons between samples can be made only within the samples evaluated on the same occasion and by the same panel. It is not possible to compare for example our numeric results with the results from other studies. In addition, the results obtained with a trained panel and the descriptive method or any other analytical sensory method do not tell which sample is 'the best' or anything else about consumer preferences.

To study consumer preferences, in Study IV, beverages and soup samples were tested with consumers without previous experience in sensory evaluation, the target age group being over 40 year-olds. The size of the study sample in Study IV varied between 353 and 410 in each of the countries. When our data were split into smaller subgroups according to different health claims, gender, age groups, the cell sizes of the data in most of the cases were close to 50, which has been suggested to be the minimum number of participants in a consumer study (Meilgaard et al. 1991). A convenience sample was used in Finland, and the recruitment locations (shopping malls, sports centres, fire stations and VTT (Technical Research Centre of Finland) were selected based on the fact that they are visited by individuals with different backgrounds. We were able to ensure that different education levels were represented in our data. The targeted age group, 40 years or over, was successfully met. It is not known how many consumers that were contacted refused to take part.

Tasting the samples in the home use situation is closer to the actual eating situation than tasting in laboratory conditions but is not fully comparable with a normal food use situation, naturally. In the test situation, the role of sensory quality is perhaps slightly more weighted than in a normal eating situation, where attention is often focused on factors other than just the food. Compared to central location tests, more information can usually be gathered in home use tests because respondents' have more time to complete the questionnaires (Meilgaard et al. 1991). A disadvantage is that researchers have no control over the testing situation; thus, the instructions have to be very clear and the amount of samples is limited in order to avoid mistakes and confusion. There may be differences between the liking scores from central location testing and home use testing, the scores obtained from home use testing being higher in many studies, but there is no overall consensus on which location would be the most appropriate (Boutrolle et al. 2005). In their study, although the scores differed between the two test situations, the liking order of the samples was the same in both tests.

The prototype food types chosen, a beverage and a soup, can be regarded as being quite familiar product types in each country, so in this respect the results obtained are comparable between countries. The questionnaires were translated from English into the three local languages: Finnish, Swedish and French. The translation may slightly change the meaning of the questions or they may be understood differently in different countries. We did not perform re-translation of the Finnish, Swedish and French questionnaires back into English, which would have improved the accuracy of the translated questionnaires.

4.2 Consumer perceptions of a healthy diet and dietary fibre

Finnish respondents in Study I mentioned similar factors as essential elements in a healthy diet, i.e. ‘vegetables’, ‘low in fat’, ‘fruit and berries’ and ‘variety’, as did respondents in the pan-EU survey (Margetts et al. 1997). Thus, in theory the elements of a health-promoting diet are known.

The respondents could correctly describe the best sources of fibre in their own diet when asked, the most frequently mentioned sources being bread, vegetables and fruit, and the result corresponded well with the actual fibre sources in the diet estimated with the fibre test. In a nationally representative Finnish study, the main sources of dietary fibre were bread, fruit and berries, other cereals and vegetables (Männistö et al. 2003), the results being similar to those obtained in our study. In our study in the interview, however, the role attributed to vegetables and fruit and berries as fibre sources was perhaps slightly overestimated compared to their actual importance. In other studies, consumers have shown to have a fairly good knowledge of fibre sources in the diet, e.g. in Northern Ireland (Barker et al. 1995) and in the USA (Sobal and Cassidy 1993). Some studies, however, have found a lack of knowledge about fibre sources, e.g. in Australia (Cashel et al. 2001) and in the UK (Whichelow 1987, 1988).

Fibre was not frequently mentioned spontaneously as a key element of a health-promoting diet, but when it was specifically asked, almost 70% of the respondents considered fibre to be very important for their health. Similarly in an American study, fibre was considered to be very healthy among women (Oakes 2003). The result of our study emphasises the importance and relevance of the appropriate phrasing of questions and how strongly this affects the responses. It is socially acceptable to regard fibre as important for health and this probably had an effect on the responses. The spontaneous situation, however, showed that the association between fibre and health is perhaps not so well realised as the link between a health-promoting diet and vegetables and fruit. In addition, the connection between a nutrient (fibre in this case) and health is understood differently than the link between a certain food or food group and health.

Currently the average intake of fibre is not sufficient in Finland; the recommended intake is 25–35 g/day (National Nutrition Council 2005) while the current intake is 21.8 g/day for men and 18.5 g/day for women (Männistö et al. 2003). Based on the results from the fibre test in our study, about one-third of the respondents altogether had an insufficient or poor intake of fibre. In particular, men in the lowest fibre intake group would need special attention in order to improve their diets. Because the fibre intake scores are not standardised by energy consumption, men's absolute points in fibre intake testing may be higher than those of women as a result of higher total food consumption. This implies that the fibre density of the men's diet (g/kJ) can be considerably lower than that of women. Consequently, men in the lowest fibre intake group are likely to have a diet with very low fibre density and have a need to significantly improve their diet quality in this sense. In Finland, the intake of fibre per kJ is lower in men (2.5 g/MJ) than in women (2.9 g/MJ) (Männistö et al. 2003).

Respondents could not estimate the amount of recommended daily fibre intake in the manner that is commonly used by nutritionists and also used as a base for recommendations given to consumers at food and portion level. This could be a problem in adopting dietary advice and in implementing it in practice. On the one hand, there is the simple and 'down-to-earth' message about the number of slices of bread to be consumed daily, or the weekly consumption frequency of breakfast cereals, but on the other hand there is public discussion, e.g. in newspapers, on the recommendations in grams. For a lay person, it is difficult to find a connection and relationships between these two means of displaying the same recommendations. When possible, for example in dietary counselling, a tailored message based on consumer's current knowledge is more effective than a general message (Brinberg et al. 2003).

The quite significant discrepancy between respondents' opinions on their own fibre intake and the result from the fibre intake test is noteworthy. About 40% of those who thought that their fibre intake was sufficient actually had an inadequate intake of fibre. In addition, over half of the respondents in the lowest fibre intake group actually considered their fibre intake to be adequate/maybe adequate. In other words, they estimated their diet quality to be better than it really was. Consumers may perceive the higher fibre intake to be socially more acceptable and hence it affected their estimations and responses; thus, they wanted to emphasise the good quality of their diet. Previously, in a Dutch population, the self-rated consumption of vegetables and fruit was much higher than the objective intake measured with a food frequency questionnaire, relating to positive beliefs concerning fruit and vegetable consumption (Lechner et al. 1997). Because in our study respondents overestimated fruit and vegetables as sources of fibre compared to their actual significance as fibre sources, it will lead to even more significant overestimation of dietary fibre intake if respondents at the same time believe that they use more fruit and vegetables than they actually do. This could partly explain the overestimation of dietary fibre intake. Overestimation of the overall quality of one's own diet has been reported earlier by Variyam et al. (2001) with American respondents. In their study, men, smokers, the higher educated and those who perceived their health status as being excellent had an increased probability of overestimating their overall diet quality.

If consumers are not aware of their current consumption frequency of fibre-rich products, it is difficult to know how and to what extent to change their eating behaviour. This was suggested by Lambert et al. (2002), in the case of the five-a-day campaign and the consumption of fruit and vegetables, to partly explain its low success rate in the USA and UK. The campaign, launched in the 1990s, aimed to increase the intake of vegetables and fruit to five portions per day. So far, it has had only a small effect on the consumption of fruit and vegetables on a national level (Lambert et al. 2002). Lambert et al. (2002) propose also that fruit, vegetables and other healthy foods could be promoted with appropriate labelling and advertising campaigns. Development and marketing of foods with additional β-glucan or some other type of dietary fibre with comprehensible product-specific claims could be more effective than just campaigning for increasing use frequencies or amounts of traditional sources of dietary fibre. The Quaker Oats case in the USA showed that a health claim regarding oatmeal products and a strong information campaign through electronic and print media improved the sale of the products and other products containing oat (Paul et al. 1999).

In our study, fibre was perceived to be equally important for health in all age groups. In some other studies, older respondents have had a higher purchase intent for a food containing fibre (Tuorila et al. 1998) and elderly women have also perceived fibre as being more important for health than young women (Oakes 2003). However, in these studies the younger respondents have been clearly younger (e.g. 15 year-olds, Tuorila et al. 1998) than the respondents in our study, who were mainly over 40-year-olds, so in this respect the results are not fully comparable. Fibre was perceived important for respondents because of its favourable effect on 'bowel function' and 'general well-being'. Respondents defined it according to its functionality and also according to the foods they thought to contain fibre. These results suggest that, when providing nutrition counselling, it is crucial to use concrete and actively used everyday terms to ensure successful and effective communication.

4.3 The effect of β-glucan on the sensory characteristics of beverages and soups

At the same β-glucan concentration, the sensory texture characteristics of beverages and soups differed significantly depending on the type of β-glucan. In beverages, the molecular weight of β-glucan varied between 60 0000 and 2 000 000 and in soups between 40 000 and 2 000 000, barley having the lowest molecular weight. Beverages and soups containing low molecular weight β-glucan were not so thick, slimy and extensible as those containing high molecular weight β-glucan. The results were as expected, as viscosity, i.e. the sensory thickness of β-glucan, is dependent on concentration and molecular weight (Wood et al. 2000). Because the concentrations were the same, the differences were caused by the varying molecular weight. The impurities of the fractions may also have a small effect on thickness but the role of molecular weight was fundamental. The strong correlations between molecular weight and thickness support this finding, which was reported earlier by e.g. Wood et al. (2000).

All β-glucan fractions in the beverage samples were from oat. Thus, the differences in texture characteristics at the same concentration of β-glucan can mostly be explained by the variation in molecular weight. In soups, the source of β-glucan was oat or barley. Therefore, besides dissimilar molecular weights of the preparations, the different texture characteristics of the soup samples can also be caused by the different cereal sources of β-glucan. Oat fractions contained higher amounts of lipids and proteins than the barley fraction, whereas the total dietary fibre and carbohydrate content of the barley fraction was higher than in the oat fractions. Components, other than β-glucan, in the preparations may also have an effect on the texture characteristics but probably their effects are less than the effect of molecular weight or cereal source of β-glucan.

Increasing thickness suppressed flavour characteristics in beverages and soups, and oat β-glucan seemed to do it more than barley β-glucan. The masking effect of viscosity has been reported earlier (Pangborn et al. 1973, Wendin et al. 1997). However, other components in β-glucan fractions may also affect the taste of beverages and soups, since the fractions were not purely β-glucan but also contained other components. The level of purity varied between 13.4 g and 34.5 g β-glucan per 100 g fraction. It is necessary to consider the effect of increasing thickness on flavour characteristics when developing products with added dietary fibre. It may be relevant to compensate for the lower perceived intensity of flavours with, e.g., additional flavour components in order to achieve the desirable flavour quality. In the study by Temelli et al. (2004), raising the concentration of β-glucan in an orange-flavoured beverage did not statistically significantly influence the flavour perception, although there seemed to be a trend of this. However, they operated over quite a narrow concentration range (0.3–0.7% β-glucan) compared to our samples which contained 0.25–2% β-glucan. Their β-glucan fraction was also purer, containing over 80% β-glucan, but they did not report its molecular weight.

As freezing of the soups did not notably affect the sensory quality, the result indicates that in this respect a frozen ready-made food product would be a suitable alternative for β-glucan enrichment. Yet, as the instrumental viscosity decreased by about 30% after the freezing treatment, it would be necessary to investigate whether it would have an effect on the physiological efficacy. On the other hand, the molecular weight remained quite stable during the freezing treatment. This finding is similar to the study by Beer et al. (1997b). However, the solubility of β-glucan decreases during freezing (Beer et al. 1997b) and therefore may influence its physiological efficacy. Because soups are eaten warm, it could alleviate the problem of reduced solubility and efficacy, because heating increases the solubility of β-glucan (Bhatty 1992, Jaskari et al. 1995).

The efficacy of β-glucan as a thickener and the influence of molecular weight on viscosity is a two-sided matter. On the one hand, as high molecular weight β-glucan is an effective thickener, it is required in smaller amounts than low molecular weight β-glucan and therefore it is cost effective. High molecular weight β-glucan is also physiologically more effective than low molecular weight β-glucan, as already mentioned, because of its viscosity-forming properties. On the other hand, high viscosity in food products, e.g. beverages, may be a negative feature in terms of sensory acceptability. Getting sufficient amounts of β-glucan into foods is a balance between sensory acceptability, physiological efficacy, food processing and also a question of price and cost effectiveness.

4.3.1 The link between instrumental viscosity and sensory characteristics

The good correlations between instrumentally measured viscosity and sensory thickness show a good performance by the sensory panel and it is possible to use instrumental viscosity measurements in estimating sensory thickness. In a study by Pangborn et al. (1978), viscosity measured at a shear rate of 30 rpm correlated very well ($r > 0.9$) with the sensory thickness of beverages. We found that viscosity measured at shear rates of both 50 s^{-1} (III) and 100 s^{-1} (II and III) correlated well with sensory thickness. In addition, many flavour characteristics correlated negatively with the viscosity of beverages and soups. The suppressing effect of viscosity on flavour has been discussed above.

4.4 Consumers' willingness to use beverages and soups containing oat β-glucan

As expected, a liking for the products was the strongest determinant for the willingness to use them. This was particularly clearly seen in beverages as the decreased liking of beverage samples containing β-glucan most likely caused a decrease in willingness to use them after tasting. Evidently, the rancid off-flavour detected by the trained panel affected liking. Taste is extremely important in food choice, in general (e.g. Glanz et al. 1998, Tepper and Trail 1998, Arvola et al. 1999), and functional foods or nutraceuticals are no exception (Jonas and Beckmann 1998, Cardello and Schutz 2003). Off-flavour of a functional food can not be compensated for by a health effect (Tuorila and Cardello 2002).

The health claim conferred additional value to beverages before tasting because the expected liking and willingness to use and particularly the perceived beneficiality were higher in β-glucan beverages with a health claim. The health claim could not compensate for the fact that the actual taste could not fulfil the expectations and consequently liking, perceived beneficiality and willingness to use decreased after tasting. The β-glucan beverage with a health claim (either cholesterol or glucose related) was, however, still perceived to be more beneficial than the β-glucan beverage without a health claim but with the same sensory quality. Bech-Larsen and Grunert (2003) found health claims to have a positive influence on the perception of food healthiness. In a real market situation, a health claim for oatmeal and an information campaign increased the sale of it and of other oat-containing products (Paul et al. 1999).

In soups, in general, neither the tasting of them nor the presence of a health claim strongly affected the responses towards the soups, but the health claim could give a small additional benefit. All the soup samples, with or without β-glucan were quite equally accepted.

Obviously, health claims had a different effect on beverages and soups. The type of carrier product that is enriched and labelled with a health claim has an impact on consumer reactions towards it (de Jong et al. 2003). First, functional foods are positioned in a particular product category according to the carrier product and only secondly are they classified as functional foods (Urala and Lähteenmäki 2003). Why then had the health claim only a small effect if any on soups in particular? If a product is perceived to be healthy, consumers do not necessarily consider such a product to be more beneficial or better when enriched (Bech-Larsen and Grunert 2003). If a soup is regarded as a low-fat food (Kähkönen et al. 1995) and therefore healthy (Oakes 2003), it is difficult to add any benefit to it with enrichments.

Overall, the health claims about the specific health effects of β-glucan had only a rather small effect on perceived beneficiality and willingness to use the beverages and soups. Therefore it would be interesting to investigate what kind of effect could be achieved with general information about the dietary fibre content of the product. As consumers positively regard products with a high fibre content because of their perceived healthiness and nutritional value (Mialon et al. 2002), a message about dietary fibre in the products could also be effective, especially when based on consumers' present knowledge (Brinberg et al. 2003).

No significant differences between countries in liking or willingness to use the beverages or soups were found, and their perceived beneficiality was similar in all three countries. French consumers perhaps emphasised more strongly their dislike of beverages with β-glucan than consumers in Finland or Sweden. In another study, French consumers have been found to seek more pleasure from food and to prefer low-fat or low-salt diets less than Belgians, Americans or Japanese (Rozin et al. 1999). At the moment, there are not very many cross-cultural studies on the acceptance of functional foods. In a Danish study, American and Danish consumers were less positive than Finnish consumers about the foods enriched with omega-3 fatty acids or oligosaccharides, but in all three countries health claims positively affected the likelihood of buying the products (Bech-Larsen et al. 2001). The researchers also emphasised the effect the enrichment type (familiar or not familiar) and the carrier product type had on the acceptance of the products. In another Danish study, Danish consumers knew less about functional foods and had more doubts about their benefits than English consumers (Jonas and Beckmann 1998). Thus, it seems that there may be some cross-cultural differences in the acceptance of functional foods, but the differences vary depending on the comparable populations and their characteristics as well as the product and enrichment type. In addition, the differences are more in the degree of acceptability and not a question of acceptance or non-acceptance.

4.4.1 The effect of age, gender and health motivation

It is understandable that the elderly would be more interested in using functional foods (Poulsen 1999, Anttolainen et al. 2001) as they are more likely have personal experience of an illnesses appearing with age than the young. In Australia, older consumers paid more attention to preventive actions regarding dietary changes, in this way possibly influencing the disease risk (Bhaskaran and Hardley 2002), and this could increase their use of functional foods.

Interestingly, in our study the effect of age on willingness to use was seen only in Sweden, where the group of consumers at age ≤ 48 years was least willing to use the beverage with a health claim. No such effect was found in other countries or in the willingness to use soups. It has been found that consumers in Finland and France share similar beliefs about the perceived benefits of healthy eating whereas Sweden was clustered with Denmark, Italy and Portugal (Zunft et al. 1997). In Finland, the extensive and systematic work at population level to lower the dietary risk factors of cardiovascular disease started with the North Karelia project in the early 1970s (Pietinen et al. 2001). Thus, the role of dietary change in preventing diseases has been widely discussed in Finland for over 30 years.

We did not find any considerable differences between women and men in their willingness to use foods with health claims. In an earlier study with a relatively small number of respondents (N = 70), women have had a higher purchase intent of functional spread (Bower et al. 2003) but another study described men to be more common users of plant sterol margarine in Finland (Anttolainen et al. 2001), and, in a third study, researchers did not find gender differences (de Jong et al. 2003). In general, women have been described to be more positive towards functional foods than men (Poulsen 1999, Urala et al. 2003). However, our finding is supported by those of Verbeke (2005) and de Jong et al, (2003) concerning the effect of gender; it does not necessarily differentiate the potential users of functional foods or the effect is highly product dependent. In addition, men suffer more from cardiovascular diseases (Statistics Finland 2003), which may make them more potential users of cholesterol-lowering products, because high cholesterol levels are one risk factor for cardiovascular diseases.

Those respondents who perceived a strong need to pay attention to blood cholesterol and glucose levels were more willing to use β-glucan *beverages* with cholesterol/glucose-related health claims. The correlations were, however, quite low in our study. Thus, personal health-related needs may be motivating factors for the use of functional foods, but their contribution to willingness to use is not necessarily considerable, which emphasises the variety of other factors affecting the willingness to use the products too. Tuorila et al. (1998) have found a link between acceptance of food labelled as 'high-fibre' and concern with fibre intake, and Bower et al. (2003) found a relationship between high health concern and high purchase intention of a spread labelled with a health benefit. The opposite could also be the case; if a person does not perceive him/herself to have a particular health problem, this may prevent him/her from buying a product labelled with a health claim related to this health problem, because there is no motivation to do so.

Interestingly, no such effect was found in the soup group. This could be explained by the more acceptable sensory quality of the β-glucan soups compared to β-glucan beverages. Because β-glucan soups were more liked than β-glucan beverages, they were easy to use as such and an additional motivation for using them was not needed for compensating for the off-flavour. Another explanation is the significant effect of the carrier product to which the health claim is attached. Urala and Lähteenmäki (2003) indicated that consumers do not perceive functional foods only as functional foods but foods within the particular product category where they belong. In addition, de Jong et al. (2003) observed that consumer characteristics of users of functional foods cannot be generalised over different food categories.

4.4.2 Willingness to pay for beverages and soups with health claims

Before tasting, consumers were willing to pay the highest price for beverages and soups with added β-glucan and a health claim. Thus, the functionality of the product was an acceptable reason for the higher price, and also consumer expectations towards the product were high. After tasting, the prices respondents were willing to pay decreased, indicating that the sensory quality of the products, both those with β-glucan and without, did not meet the expectations. It is obvious that the defective sensory quality of beverages with β-glucan caused this decrease for its part. In soups, the drop in the prices was not so dramatic. The prices estimated before tasting seemed to be quite unrealistic and did not correspond to the prices respondents actually would be willing to pay.

The sensory quality of the functional products has to be acceptable for consumers and, only after this, are they willing to pay a certain additional price for the beneficial health effect. There are probably consumer groups who, given any conditions, are not willing to pay extra for functional foods, but there are also those for whom price is not so important a determinant in making a buying decision (Poulsen 1999). In a Danish study, consumers were not willing to pay extra for products with functional benefits (Jonas & Beckmann 1998). Among Finns too, the price of functional foods is important in making buying decisions (Ollila et al. 2004).

The correlations between willingness to use and willingness to pay indicate a link between these two factors but, as the correlations were only moderate, they measure and mean different things for consumers. A higher price is not linearly accepted although willingness to use a product would be strong.

Good correlations were obtained between willingness to pay to try a product and to regularly buy a product, indicating that if respondents were willing to pay a higher price to try a product, they also were willing to pay a higher price to regularly buy a product.

4.5 Feasibility of beverages and soups with added β-glucan

Technologically, low molecular weight β-glucan was easier to add into a product at higher quantities because it produced a lower viscosity than high molecular weight β-glucan. Yet, high molecular weight is important for the physiological efficacy of β-glucan. Because of this, the addition of β-glucan into foods could be done from two different perspectives. The low molecular weight β-glucan could be added into foods as dietary fibre, in general, not considering the proven cholesterol-lowering and blood glucose-balancing effects and the requirements for achieving them. Nevertheless, β-glucan is a type of dietary fibre and the food with added β-glucan could be marketed as 'fibre-enriched'. As the health claims about the cholesterol-lowering and blood glucose-balancing effects of β-glucan had only quite a small effect on their perceived beneficiality and willingness to use them, general information about the fibre content of the product could be equally effective and generate the same positive image for the product as a specific health claim would.

However, another question is whether a relatively pure fibre concentrate could bring the same beneficial effects as the dietary fibre in vegetables, fruit and cereals, although the dietary fibre intake would certainly be improved with a product containing added fibre. The health benefits of fibre may be mediated also via other compounds and substances in a diet rich in dietary fibre, because the mechanisms behind the health effects of dietary fibre are not completely understood.

Another strategy is to add high molecular weight β-glucan as a special functional ingredient and aim at producing a food product with a product-specific effect and a health claim about the cholesterol-lowering and/or blood glucose-balancing effects.

Beverages and soups or similar products with added β-glucan could be feasible sources of β-glucan in the diet. Even at quite low concentrations, e.g. 0.5% β-glucan, a 250-ml portion of a beverage would contain 1.25 g of β-glucan, which is almost half of the daily amount recommended by the FDA in the USA. In soups, the same β-glucan concentration in a 300-ml portion of soup would result in a 1.5-g dosage of β-glucan from a single portion. Hence, the daily intake of 3 g β-glucan could be achieved by consuming one to two portions of different types of foods with added β-glucan. If the β-glucan concentration were 2%, which it was possible to achieve with the low molecular weight preparations, a single 250-ml portion of a beverage would provide 5 g β-glucan and a 300-ml portion of soup 6 g β-glucan.

To whom should foods with added β-glucan be targeted? Targeting them to the whole population would aim at increasing the dietary fibre intake at population level, which in turn, if successful, could have a significant effect on public health. Particularly, this could be a possible strategy if β-glucan were added into products as dietary fibre in general. However, it is essential to consider the possible differences in health effects arising from dietary fibre occurring naturally in foods and those resulting from added fibre concentrate. On the other hand, the products could be targeted at persons suffering from high cholesterol levels or diabetes, who would benefit from balanced blood glucose values if β-glucan were added as a special functional ingredient. In this case, these particular patient groups would benefit if the use of these products were sufficient in terms of mediating health effects, and if the quality of the rest of the diet did not deteriorate. The question about an appropriate target group is a complex issue. Among Dutch dieticians, 9 out of 10 respondents felt uncertainty about the overall target groups of functional foods (de Jong et al. 2004). In addition, the appropriate target group from a public health perspective may be different from the food manufacturer's point of view, taking a commercial approach. Further research is needed on how products enriched with dietary fibre affect the total dietary fibre intake in different target groups.

5. Conclusions

The general aim of this thesis was to investigate whether foods enriched with a fibre component, namely β-glucan, would produce a feasible strategy for improving consumers' dietary fibre intake. Both consumer aspects regarding dietary fibre and fibre-enriched products, and product-related factors were studied.

Finnish consumers regarded dietary fibre as being important for their health. However, the contradiction between perceived and self-estimated intake of fibre can be an obstacle to improving the quality of the diet through nutrition education among particular groups of consumers, because the misperception may prevent implementation of the actually needed dietary changes. The contradiction may result from overestimating the use of foods rich in fibre in the diet, overestimating some foods as dietary fibre sources and unrealistic optimism concerning the quality of one's own diet. Since the results indicate that consumers generally have a positive attitude towards high-fibre products, products either naturally containing fibre or with added fibre could be acceptable.

Enriching non-traditional foods with dietary fibre with a label informing on fibre enrichment could be a possible approach to improving dietary fibre intake, especially among those whose diet does not naturally contain sufficient traditional sources of dietary fibre. For these consumers, general nutrition education is not necessarily effective enough to ensure the inclusion of an adequate amount of traditional dietary fibre sources in the diet.

The sensory quality of beverages and soups with added oat or barley β-glucan was acceptable and the sensory characteristics of the soup did not change during freezing. Beverages and ready-to-eat frozen soups could be feasible carriers for β-glucan and thus provide a non-traditional source of dietary fibre. In product development it is important to take into account the increasing thickness and suppression of flavour characteristics caused by the added β-glucan fraction which could be counteracted, for example, by adding some flavour components, and it could be interesting to study this aspect further.

Overall, low molecular weight β-glucan was easier to add into a product at higher concentrations in terms of the sensory properties, but it is important to bear in mind the importance of high molecular weight β-glucan for its physiological efficacy. One strategy could be to add β-glucan into foods as dietary fibre, in general, aiming only at the increased fibre content of the food, while at the same time keeping in mind that the health effects of fibre concentrates and dietary fibre naturally present in foods may differ. In this case the low molecular weight β-glucan could be a suitable alternative as it can be added into foods at higher concentrations than high molecular weight β-glucan and still maintain feasible sensory properties. Another approach would be to add high molecular weight β-glucan and aim at the specific physiological efficacy of these foods.

Liking for beverages and soups was the strongest determinant for the willingness to use them, and therefore the taste and other sensory characteristics of foods with added β-glucan are key factors for the regular use of the products. The present study demonstrated that further research is needed for tailoring the sensory quality of the fibre-enriched products to make them more palatable. In particular, the off-flavour detected in beverages containing β-glucan showed the importance of the development of suitable process methods for β-glucan products. As the specific health claims gave only a small additional value to beverages and soups, general information about the fibre content of the product could be equally effective, because dietary fibre as such is positively linked with health in consumers' minds. The many different characteristics of a food product have to be in favourable balance for consumers in order to enhance the product acceptability and success in the market. Healthiness of food is, however, only one product feature and selection criterion among many others.

Dietary fibre-enriched foods might be valuable especially in snack and prepared food markets as their increasing consumption patterns could be utilised by offering new fibre sources in this category. However, the role of the new fibre-rich foods in the total intake of dietary fibre should be investigated in different target groups before conclusions can be made about whether they provide a feasible strategy for improving consumers' fibre intake.

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PUBLICATION I

Perceived role of fibre in a healthy diet among Finnish consumers

In: Journal of Human Nutrition and Dietetics 2004.
Vol. 17, pp. 231–239.

Perceived role of fibre in a healthy diet among Finnish consumers

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Keywords
consumers, dietary fibre, healthy diet, perception.

Abstract

Objective The aim was to study how Finnish consumers perceive the role of fibre in the diet, which foods are regarded as good sources of fibre and the relationship between the respondents' self-estimated fibre intake and their measured intake.

Methods A semistructured interview was conducted with 125 volunteers, including a background information questionnaire and an easy-to-use self-administered paper-and-pencil form estimating fibre intake.

Results According to the self-administered form about half of the respondents had adequate fibre intake. Among those who estimated their fibre intake as adequate/maybe adequate, only 61% belonged to the highest fibre intake group. Most of the respondents defined their diet as being healthy. The key elements for a healthy diet were 'vegetables', 'low in fat', 'fruit and berries' and 'variety'. Only 5% of the respondents mentioned fibre spontaneously here. However, fibre was considered important for health because of its effect on bowel function and general well-being. The recommended intake of fibre could not be described in nutritional terms, but respondents could identify relevant sources of fibre in the diet.

Conclusion Finnish consumers considered fibre important for health and could recognize the sources of fibre correctly although they did not mention it spontaneously as a part of a healthy diet.

Introduction

In recent decades, many studies have established the positive association between intake of dietary fibre and decreased risk of several diseases such as colorectal cancer (Jansen *et al.*, 1999; Bingham *et al.*, 2003; Peters *et al.*, 2003) or cardiovascular diseases (Liu *et al.*, 2002). Adequate fibre intake has also been shown to improve glucose/insulin metabolism and lower plasma lipid concentrations in type 2 diabetes patients (Chandalia *et al.*, 2000). There are theories explaining the possible mechanisms behind the effect of fibre on health but in many cases these mechanisms have not been fully understood and the evidence is based on correlations between the amount of fibre in diet and the prevalence or incidence of a certain disease.

The intake of dietary fibre (NSP = nonstarch polysaccharides meaning the indigestible part of carbohydrate-rich foods which does not yield energy) is below the current Finnish recommendations: the average intake of dietary fibre is 21.8 g day^{-1} for men and 18.5 g day^{-1} for women (Männistö *et al.*, 2003) whereas the recommended intake is 25–35 g day^{-1} (National Nutrition Council, 1998). To improve the fibre intake, we have to analyse how consumers think about fibre, what foods are considered to be good sources of fibre and whether fibre is considered as an important factor in healthy eating.

Generally, European consumers seem to know, at least at a verbal level, what a healthy diet, as recommended by nutritionists, should be like. In a pan-EU survey, 80% of the respondents mentioned 'more fruit and vegetables' or 'less fat' or 'balance and variety' when describing their perceptions of a healthy diet (Margetts *et al.*, 1997). In the Finnish subpopulation, the most frequently mentioned definitions were 'more fruit and vegetables, less fat/fatty foods/low fat diet' and 'balance and variety', mentioned by at least 42% of the respondents. Fibre was not mentioned very frequently without prompting, as 'more staples, fibre' was mentioned only by 22% of the Finnish respondents.

The insufficient level of general knowledge about fibre as a factor in a healthy diet may be an obstacle to its increased intake. The level of the subjects' nutritional knowledge has been associated with their intake of fat, fruit and vegetables (Wardle *et al.*, 2000). It is also quite common to perceive one's own diet quality to be better than it really is (Variyam *et al.*, 2001). This misperception, 'unrealistic optimism' may prevent beneficial dietary changes.

The relationship between nutrients and foods may be confusing for consumers. In the UK, the Health and Lifestyle Survey showed that <30% of the respondents correctly classified eight or more food items according to the fibre content among a total of 10 food items (Whichelow, 1987, 1988). However, Sobal & Cassidy (1993) found American respondents' rating of the amount of fibre in 40 foods reasonably similar to the chemical data about the fibre content in these foods. Australians could not recognize specific food sources of fibre although the general relationship between fibre intake and its food sources was understood (Cashel *et al.*, 2001). In Ireland, an increased perceived importance of fibre in health was correlated with a high intake of fibre through increased intake of potatoes, vegetables, wholemeal bread and fruit indicating an understanding of the main food sources of fibre (Barker *et al.*, 1995).

The aim of this work was to study how consumers perceive the role of fibre in a healthy diet, what foods are regarded as being good sources of fibre and the relationship between the respondents' self-estimated fibre intake and the intake estimated with a self-administered fibre test.

Materials and methods

The participants for this study were volunteers recruited from libraries, public swimming pools and shopping centres. The size of the study sample was 125 participants, of which 34% were from Kuopio, a town in the eastern part of Finland, and 66% from Helsinki, the capital of Finland. The 'response rate' was 80%, which means that 156 volunteers were contacted, and 20% (31) of them declined to take part. The commonest exclusion criterion was the respondent's age being under 18 years. The distribution of respondents' sociodemographic characteristics was fairly close to the overall Finnish population (Table 1). The proportion of men and women was close to even, and the age groups were equally represented. On average in Finland (year 2001), 39.8% of the population had completed only the basic education level, 36.5% had a secondary education and 23.7% had a higher education level (Anonymous, 2001). Our study population was slightly higher educated than the average Finnish population, but all education levels were represented.

Interview

A semistructured interview was used as a study method. At the start, questions about the respondent's perception of a healthy diet in general were presented. This was followed by questions on the function, possible sources and

Table 1 The frequency distributions of residence, sex, age and education of the respondents

	n (%)
Total (*N*)	125 (100)
Residence	
Kuopio city	43 (35)
Helsinki city	82 (66)
Sex	
Male	61 (49)
Female	64 (51)
Age (years)	
18–30	38 (30)
31–49	46 (37)
50+	41 (33)
Education (years)	
Basic education level (duration 9)	18 (15)
Secondary education (11–12)	50 (40)
High education level (13+)	57 (46)

required amount of dietary fibre. In the last part of the interview, the respondents were asked who could and should provide information about dietary fibre, and finally, some additional questions were asked about the use of bread. The fibre information and the bread-related questions and results are not reported here. All of these questions were open-ended with no preset response alternatives.

Before the actual interview, some general information was given about the study, such as the time required to participate in the survey and that the theme was health in general. The interviewees did not know in advance that the target interest was in dietary fibre. This was important in observing whether dietary fibre would be spontaneously mentioned in answers to the healthy diet-related questions. The interviewer used a laptop computer to record notes during the interviews and the interview was also recorded on tape. The usual duration was around 30 min per interview.

Background questionnaire and fibre intake test

After the interview, the participants filled in a background information questionnaire on socio-demographic factors, their own assessment of their state of health and confidence in different sources of information regarding dietary fibre (the latter ones are not reported here). They also completed a fibre intake test (Appendix 1; Finnish Bread Information, 1999). Both of these only asked questions with preset answer options. The fibre intake test was developed by Finnish Bread Information (1999) and validated with food diaries in 2000 (A. Wegelius, unpublished data). The idea behind it is to provide a fast, easy-to-use rough method for consumers to assess the amount of dietary fibre in their own diet. The test includes eight product categories, which are relevant sources of dietary fibre in Finland. The categories are further divided into subcategories, for example, in the case of bread, into different bread types from rye bread to wheat toast. Consumers mark the number of portions of each food item they ate the day before. The portions of the food items are converted into points; one point is approximately equivalent to 1 g of dietary fibre. The test is not able to provide an exact result of fibre intake but gives a rough estimate and it is possible to compare respondents' fibre intakes. As a result, the consumer can be categorized into one of the following groups, based on the amount of points gained in the test: adequate intake of fibre (≥25 points); almost adequate intake of fibre (21–24 points); insufficient intake of fibre (15–20 points); poor intake of fibre (<15 points in the fibre test).

This classification is also used in the analysis of this work. The fibre intake measured is an absolute value in points, and hence not standardized by energy intake.

The data were collected between April and June 2001 by one interviewer. Volunteers received information about their dietary fibre intake from the fibre intake test and were given a small gift as a reward.

Data analysis

The notes written during the interviews were checked against the tapes. The responses were categorized according to their content. The categories were formed during examination of the data, so that those issues that were mentioned by at least four respondents formed an independent category. Issues that were mentioned three times or less were included in the category 'others'. During the analysis, the categories could be further combined based on their content, if their meaning was regarded as being close to each other. With this approach, the responses could be divided into a reasonable number of categories. The number of respondents mentioning an item was calculated. Mean values were calculated from the background information questionnaire data. Cross-tabular distributions of frequencies were tested with the chi-square test. SPSS software (version 10.0.5, SPSS Inc., Chicago, IL, USA) was used for the statistical analysis.

Results

The intake and sources of dietary fibre according to the fibre test

According to the results from the fibre test, about half of the respondents (51%) could approximately be described as likely to have an adequate intake of fibre and 14% as likely to have an almost adequate intake of fibre. About one-fifth of the respondents (22%) seemed to have an insufficient intake and 12% a poor intake of fibre. Over half of the men (56%) and under half of the women (47%) belonged to the highest intake group. A bigger proportion of men (16%) than women (8%) belonged to the lowest intake of fibre group, but the difference was not statistically significant ($P = 0.17$; chi-square test). It has to be kept in mind that the fibre intake points are not standardized by energy intake and as a consequence men's absolute fibre intake points may be higher than women's due to the usually higher energy intake. Based on the approximate fibre test, the main source of dietary fibre was clearly bread, contributing over half of the fibre intake, followed by vegetables and fruit and berries (Fig. 1).

Defining a healthy diet

The interview began with general, open questions on what constitutes a healthy diet. Most of the respondents assessed their own diet as being healthy (62%) or at least moderately healthy (12%). Only 14% evaluated their own diet as being unhealthy, whereas the remainder of the population (12%) was unsure about the healthiness of their diet.

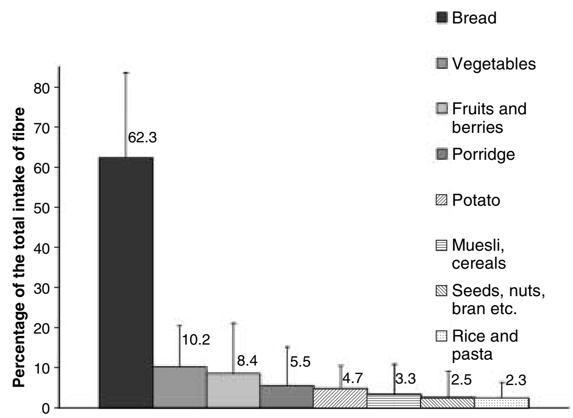

Figure 1 The sources of dietary fibre in the diet (percentage of the total intake of fibre, mean and SD).

The respondents were asked what they considered to be key elements of a healthy diet. At this point over half of the respondents (58%) mentioned 'vegetables'. Also 'low in fat' (34%), 'fruit and berries' (22%) and 'variety' (20%) were frequently mentioned. 'Fibre' was spontaneously mentioned by only 5% and 'bread' by 10% of the interviewees.

To the question 'What would you change in your diet, if you would like to have a healthier diet', the most frequently mentioned responses were 'more vegetables' (43%), 'less sweet delicacies' (26%), 'less fat' (18%), 'more fruit' (14%) and 'more fish' (10%). Only 5% and 4% of the respondents mentioned 'more cereals/porridge' or 'less bread', respectively.

Perceptions of dietary fibre

Definition of fibre

When respondents were asked with an open question to define dietary fibre and describe the role of dietary fibre in the diet using their own words, 89% of the respondents could define dietary fibre in some way although fibre had not been mentioned often as part of a healthy diet. Fibre was very often defined by food items, which the respondent thought to contain fibre. Vegetables were most often mentioned (by 42% of the respondents) in this context, followed by cereals (33%), fruit (27%), bread (25%) and porridge (19%). Dietary fibre was also defined by its function in the body. Among these so-called functional definitions, 'related to bowel function' (35% of respondents), 'related to stomach function' (24%), 'related to digestion' (23%) and 'makes one feel full, decreases appetite' (12%) were the most frequently mentioned effects. Only about one-tenth of the respondents (11%) could not say anything about dietary fibre.

The amount of fibre in the diet

We were interested to know whether consumers could evaluate their fibre intake using nutritional terms, as this is often the way in which advice is given by experts. The interviewees were asked how much dietary fibre they thought they should consume daily. Three-quarters of the respondents did not know the recommended amount. Only 13% claimed to know the recommended amount and 12% thought that they might know it. The amount estimated by interviewees varied from '800 mg' to 'two-third of the entire food intake'. It seems that although people claim to know the recommended amount their responses could be very unrealistic in nutritional terms.

The following questions dealt with their opinion on the adequacy of dietary fibre in their own diet, the best sources of dietary fibre in their diet, and how to improve the intake of dietary fibre. Three-quarters of the respondents (74%) thought that their diet contained 'adequate/maybe adequate' fibre. Approximately one-fifth (21%) considered the amount of fibre in their diet 'inadequate' or 'maybe inadequate', and 6% could not estimate the amount of fibre in their diet at all.

The results from the fibre intake test were compared with the respondents' own estimations of their intake of dietary fibre. Of those who estimated their fibre intake to be 'adequate/maybe adequate', only 61% belonged to the highest fibre intake group, and 25% actually had a poor or insufficient intake of fibre (Fig. 2). Those who estimated their fibre intake to be 'inadequate/maybe inadequate' mostly belonged to groups of poor or insufficient fibre intake, but about one-fifth of them actually had adequate fibre intake (Fig. 2). Also noteworthy, two-thirds of the respondents (67%) in the lowest fibre intake group (poor intake) thought that their fibre intake was 'adequate' or 'maybe adequate', and only 34% thought that it was 'inadequate/maybe inadequate'.

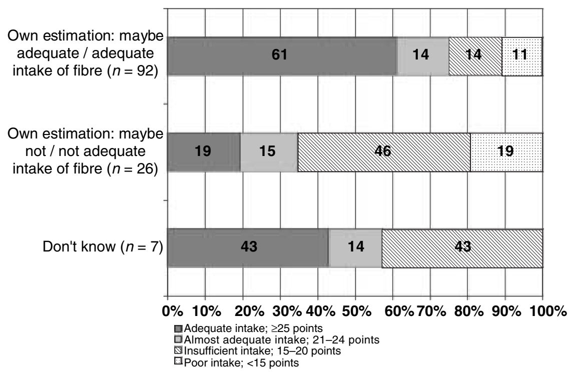

Figure 2 The personal estimation of the respondents' fibre intake and the actual fibre intake based on the results from the self-administered fibre intake test.

The sources of fibre in the diet

The respondents were then asked to freely describe the best sources of fibre in their diet with the possibility to mention several options. Bread (mentioned by 76% of respondents), vegetables (38%) and fruit (29%) were mentioned most often as the best sources of dietary fibre. We also asked how they would improve their intake of fibre if necessary. The respondents had the opportunity to mention several options here. The most common ways to improve fibre intake were to increase the use of bread (mentioned by 30% of respondents), vegetables (26%), bran (13%), porridge (10%) and fruit and berries (10%).

Compared with the results from the fibre intake test the relevant sources were correctly identified, although the role of vegetables, fruit and berries was slightly overestimated as sources of fibre compared with the actual proportion they contributed in the fibre intake test.

The role of dietary fibre in a healthy diet

The interviewees were asked if an adequate intake of fibre was important for their own health. In general, 68% of the respondents thought it was very important and 11% moderately important. Only 9% said that fibre intake was irrelevant to their health. There were no statistically significant differences between age groups regarding the importance of fibre for health.

When asked to describe why an adequate intake of fibre was important for their health, 39% of the respondents mentioned 'bowel function' as an important influence of dietary fibre, whereas 'general well-being' was mentioned by 29%.

Discussion

The fibre intake test used gives an estimate of fibre intake and it can be used to divide respondents into different fibre intake categories. Each point in the test is based on a rough estimate of the amount of food product required to give an intake of 1 g of fibre. Although this is an approximation, it provides a quick tool for roughly assessing the intake of fibre and for grouping respondents according to their intake; however, the test should not be used for direct conversion of points into fibre intake grams. The self-administered test may have a tendency to overestimate the intake if points and grams are compared. In this study, the average points for men and women were 33 and 27, respectively, whereas the average intake among the Finnish population is 22 and 19 g day^{-1} when measured using 48-h dietary recall (Männistö *et al.*, 2003). This difference can be explained partly by the approximate nature of the self-administered test and partly by the discrepancies in respondent populations, but also the nature of the test may have an influence. In the self-administered test all choices increase fibre intake and the social desirability of a healthy, high-fibre diet may have an impact on reporting higher fibre intakes. Points based on the self administered measure are likely to give more optimistic results on fibre intake than what is the reality and this should be taken into account when results are examined.

According to the fibre test, half of the respondents had an adequate intake of fibre, whereas about one-third had an insufficient or poor intake of fibre. Men usually have a higher energy intake than women, which means that their fibre intake per kJ is significantly lower than that of women. Therefore, men in the lower fibre intake groups are likely to be a problematic group. In a nationally representative study in Finland, the mean daily intake of fibre was 2.5 g MJ^{-1} in men and 2.9 g MJ^{-1} in women (Männistö *et al.*, 2003). In the same study, the main sources of dietary fibre for men were grain products (66%), vegetables and potato (12%) and fruit and berries (10%) and for women 54%, 14%, and 17%, respectively, measured as grams based on 48-h dietary recall. We found similarities in our study; according to the fibre test, the main sources of dietary fibre were grain products, vegetables and fruit and berries.

The principles of a healthy diet were known in theory, as fruit and berries, vegetables and a diet low in fat were the most frequently mentioned descriptions of a healthy diet. The finding is similar to the results from the Finnish subpopulation in a pan-EU survey (Margetts *et al.*, 1997). The role of vegetables and fruit and fat in a healthy diet has been widely discussed in recent years in Finland, which can be seen from these results. The results also reflect the Finnish nutrition recommendations suggesting in the so-called 'plate model' that half of the plate should be filled with vegetables (National Nutrition Council, 1998). Dietary fibre was not connected with a healthy diet without prompting, but was regarded as important when it was specifically asked about.

The majority of the respondents were able to define dietary fibre in some way. Most often dietary fibre was defined by food items thought to contain fibre. In these definitions, greater emphasis was placed in the consumption of vegetables and fruit compared with their actual role as a fibre source. Cereals and bread were also frequently mentioned, which indicates that people know what good dietary sources of fibre are, as also observed in other studies (Barker *et al.*, 1995; Cashel *et al.*, 2001). Dietary fibre was also defined according to its bodily functions and mostly linked to stomach function and digestion, which are perhaps the traditionally discussed effects of fibre. It seems that the role of fibre in many specific diseases is not clear to consumers but they seem to know where dietary fibre comes from and its functions in the body. However, there was a small group of consumers who could not say anything about fibre. In this sense, nutrition education related to dietary fibre has been quite successful in informing about what should be eaten and what the result is, but has not being able to explain the reason behind the advice.

The respondents' own estimation of their possible inadequate fibre intake was relatively good, as the majority of those estimating their fibre intake as being inadequate/may be inadequate actually had an inadequate intake of fibre according to the fibre test. However, a group of respondents also estimated their fibre intake to be adequate/maybe adequate and yet they actually had an inadequate intake of fibre. Variyam *et al.* (2001) concluded in their study that it is common to perceive one's own diet quality to be better than it actually is. These misperceptions may prevent the actual necessary dietary changes.

The recommendations concerning the amount of dietary fibre were not known to participants. It seems that lay people do not think about food in nutritional terms, which means that it is difficult for them to estimate the recommended amounts or the effects of single factors in diet. However, it is not necessarily an obstacle to healthy eating, as in this population the most significant sources of dietary fibre were correctly recognized. Perhaps the 'professional' way of concentrating on grams and general advice is not successful in dietary counselling. A more fruitful way could be focusing on broader concepts, such as 'eat wholegrain bread at every lunch' or 'eat porridge four times per week'. Also, emphasizing the use of wholegrain products among cereal products in dietary counselling could be effective.

The majority of the interviewees perceived fibre to be important for health although it was not spontaneously mentioned as part of a healthy diet. It was commonly seen as a key factor in gut health and well-being. However, we have to keep in mind that as health-related issues had been discussed in previous questions, this may have an effect on their attitude and answers to this question and perhaps some considered fibre more important because the focus of the study was on fibre and health issues.

In conclusion, fibre was not mentioned spontaneously as being a part of a healthy diet, but when prompted, the majority of the consumers considered it important for their own health. The consumers were aware of the dietary sources of fibre, but they slightly overestimated some foods as sources of fibre. Personal perception of fibre intake reflected the roughly estimated fibre intake, but yet about 40% of respondents who perceived their fibre intake as being adequate actually had an inadequate intake of fibre. Consumers did not know about the recommendations concerning fibre, and they could not think about fibre in nutritional terms.

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Appendix 1 Fibre intake test (Finnish Bread Information, 1999)*. In each food category please mark the amount that corresponds with what you ate yesterday

Bread and cereals	Number of slices/pieces	Points/slice or piece*
Rye bread with grains (Ruismax, RuisReal)		5
Other kind of soft rye bread or crisp bread, mixed grain bread with grains (Jyvämax, MoniviljaReal)		3
Mixed/oat/barley/wholemeal bread, Karelian rice pasty, bun, berry pie, thin rye crisp		2
Toast, French bread, croissant		1
Rice pasty, piece of pizza (10 × 10 cm^2), one large thin pancake or four small ones		1
Muesli, breakfast cereals, etc. (1 portion = 1 dL-20 g^{-1})	Number of portions	Points/portion*
Breakfast cereals rich in fibre (All-Bran Plus)		6
Breakfast cereals with fibre (All-Bran Regular)		3
Regular breakfast cereals		0.5
Muesli		1.5
One piece of Weetabix		2
Porridge (1 portion = 2.5 dL)	Number of portions	Points/portion*
Whole grain flake porridge		4
Rice porridge or semolina pudding		1
Oat bran porridge		6
Seeds, nuts, bran, dried fruit, etc. (1 portion = 1 tbs)	Number of portions	Points/portion*
Nuts, sunflower or other seeds, bran		1
Flax seeds		3
Raisins		1
One dried plum or date		0.5
One dried apricot		1
Fresh berries and fruit	Number of portions	Points/portion*
1 portion = one piece of fruit or 1 dL berries		2
Vegetables (1 portion = 1 dL)	Number of portions	Points/portion*
Fresh peas, cooked beans, maize, mixed frozen vegetables (e.g. pea-maize-bell pepper)		3
Grated fresh vegetables, mixed salad, cooked or fresh vegetables		1
Potato (1 portion = 1 dL or 1 piece)	Number of portions	Points/portion*
Cooked potatoes		1
Mashed potatoes, potato salad, French fries, fried potatoes, garlic potatoes		1
Rice and pasta (1 portion = 1 dL cooked food)	Number of portions	Points/portion*
White rice		1
Whole grain rice or rice–rye mix		2
Regular macaroni		0.5
Oat macaroni or rye macaroni		1
	Total points*	

*This information was given to respondents only after they had completed the test. The respondents had not been informed in advance that the specific interest of this test was fibre.

PUBLICATION II

Influence of oat β-glucan preparations on the perception of mouthfeel and on rheological properties in beverage prototypes

In: Cereal Chemistry 2003.
Vol. 80, No. 5, pp. 536–541.
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Influence of Oat β-Glucan Preparations on the Perception of Mouthfeel and on Rheological Properties in Beverage Prototypes

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ABSTRACT

Cereal Chem. 80(5):536–541

The aim was to study the effect of concentration and molecular weight of four different β-glucan preparations on the perceived sensory quality of a beverage prototype. The correlations between sensory and instrumental measures were investigated. Two of the preparations were bran-type containing high molecular weight β-glucan, two were more-processed low molecular weight β-glucan preparations. Twelve beverage samples containing 0.25–2% β-glucan and one reference sample thickened with carboxymethyl cellulose (CMC) were profiled by a sensory panel and analyzed by instrumental measurements (viscosity and molecular weight). Sensory profiles of the beverages varied at the same concentration of β-glucan, depending on β-glucan preparation. Beverages made with the bran-type preparations were more viscous and had higher perceived thickness than beverages made with more-processed, low molecular weight preparations. Moderate correlations were obtained between perceived thickness and sliminess and instrumental viscosity at all shear rates between 26 and 100/sec (r = 0.63–0.78; $P \leq 0.001$). Technologically, more-processed β-glucan preparations are easier to add into a beverage in amounts sufficient for achieving a physiologically functional amount of β-glucan in a product.

The soluble oat fiber β-glucan has a moderating effect on postprandial blood glucose and insulin response (Braaten et al 1991; Wood et al 1994) and reduces elevated blood cholesterol levels (Ripsin et al 1992; Rimm et al 1996). The U.S. Food and Drug Administration (FDA) allows a generic health claim for oat and oat products concerning the cholesterol-lowering effect of soluble fiber (e.g., β-glucan) in reducing the risk of coronary heart disease (FDA 1996).

Presently, added β-glucan is being used mostly in cereal products. New types of foods containing β-glucan are needed to promote the use of 3 g of β-glucan/day, which is the amount defined by the FDA as the limit for potential health effects. One possibility for a new β-glucan-containing product category is beverages. Growth in the functional drinks sector has been strong over the last few years and is estimated to continue (Potter 2001; Sloan 2002).

The behavior of β-glucan in beverages is an interesting, unexplored field. Especially, the high viscosity of β-glucan is expected to influence both sensory quality and physiological functionality. Viscosity of β-glucan is mainly determined by concentration and molecular weight (Autio 1995; Wood et al 2000). The larger the molecular weight or the concentration of β-glucan is, the higher the viscosity. An inverse linear relationship between glycaemic response and viscosity of an oat β-glucan solution has been established (Wood et al 1994). Yet there is no evidence of the significance of molecular weight on the efficacy of β-glucan in reducing blood cholesterol levels. Processing may decrease the molecular weight of β-glucan (Beer et al 1997). In the study of Önning et al (1999), a processed oat product (oat milk) was found to be effective in reducing blood cholesterol levels.

The sensory quality of food is one of the main factors influencing the repeated food choices of novel products (Arvola et al 1999). To assure the consumption of β-glucan-containing foods, and thereby enable the positive health effects of β-glucan, products have to have an overall acceptable sensory quality and bring pleasure to consumers. The viscosity effect of β-glucan, however, may cause problems from the food processing perspective. The low molecular weight β-glucan has, perhaps, better sensory characteristics in food products than high molecular weight β-glucan due to lower viscosity, but the evidence on physiological efficacy of low molecular weight β-glucan has not yet been well established (Wood and Beer 1998). Designing foods rich in β-glucan with high molecular weight is challenging task, and so far very few studies have systematically studied the effect of β-glucan on the sensory quality (Mälkki et al 1993; Inglett et al 1994; Zoulias et al 2000). None of these studies has been conducted with beverages as a model food.

The objectives of this research were to investigate how concentration and molecular weight of four β-glucan preparations affect the perceived sensory quality, including thickness, and whether correlations between sensory and instrumental measurements are affected by the different shear rates used in the measurement of instrumental viscosity in a beverage prototype.

MATERIALS AND METHODS

β-Glucan Preparations

Four different β-glucan preparations (BG1–BG4) were used for preparing the beverages. BG1 and BG2 were oat bran, rich in β-glucan, produced by dry milling at Avena Oat Ingredients (Helsinki, Finland). BG3- and BG4-preparations were soluble β-glucan preparations from CEBA AB (Lund, Sweden), produced by aqueous enzyme-aided extraction. The composition of β-glucan preparations is presented in Table I. β-Glucan content of the preparations was determined enzymatically by the Megazyme method (McCleary and Codd 1991). The average molecular weights (M_w) of the preparations were analyzed after their isolation and purification by using right-angle laser light scattering. The beverage samples were analyzed by HPLC-SEC with calcofluor staining (Suortti 1993) to prove the preservation of the molecular weight during preparation.

Carboxymethyl cellulose (CMC) (Carmellos.natr; Yliopiston Apteekki, Helsinki, Finland) was used as a thickening agent instead of β-glucan preparation in the reference beverage. Orange-flavored frozen juice base (Döhler, Darmstadt, Germany) was used as the basic component in preparing the beverages.

Preparation of Beverage Samples

The beverages were prepared by mixing the β-glucan preparation with water, sucrose (household quality), and α-amylase. Termamyl 120L type L (Batch AXN 04123, Novo Nordisk A/S, Denmark) was used to hydrolyze the remaining starch from β-glucans in the beverages. It was heat-treated before use to inactivate possible endogenous β-glucanase by heating 100 mL of 23.5%

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Publication no. C-2003-0724-01R.

(v/v) Termamyl with 12 mM $CaCL_2$ in a boiling water bath for 15 min. The solution was sieved through lens-cleaning tissue and used at 2% (v/v) concentration. The Termamyl enzyme was used only in BG1 and BG2 beverages because starch was already removed from BG3 and BG4 preparations during processing. The mixture was then blended with Bamix blender bar for 15 sec, after which the mixture was heated in beakers up to +75°C in a water bath (+80°C) for 15 min. After heating, the mixture and orange juice base were blended together so that the final concentration was 5% juice base and 9% sugar in beverage samples. The beverages were cooled at room temperature and stabilized for 20 ± 3 hr at room temperature. The reference sample (CMC) was prepared in the same way but heated directly on a stove to almost the boiling point. The viscosity and molecular weight of β-glucan was determined from each batch.

The β-glucan concentrations in the beverages varied from 0.25 to 2.0% (w/w) (Table II). The concentrations were selected based on preliminary trials. The concentration of CMC in the reference beverage sample was 1.3%. The beverages varied at pH 3.5–4.2.

Sensory Evaluation

The experienced sensory panel had 20 members, five of whom took part in the development of vocabulary; 9–10 members took part in each evaluation session. The sensory characteristics of the beverages were evaluated using descriptive analysis (Lawless and Heymann 1998). Attribute intensities were rated on 10-unit graphic intensity scales, verbally anchored from the ends (Table III).

The vocabulary was developed in one session. Panelists tasted six different β-glucan beverages and then described the texture and flavor characteristics. Altogether, 11 attributes were selected to describe texture, mouthfeel, and flavor of the beverages. For each attribute, except the total flavor intensity, models were created for training the panel (Table III). For the sensory evaluation, detailed instructions for the panelists on evaluation technique for all attributes were written up to be used during the evaluations.

The panel was trained in three training sessions within 12 weeks. During the first training session (duration ≈30 min), the models of the attributes were presented to the panelists to familiarize them with the attributes. Directly after this, the training session continued with two samples that were evaluated on graphic scales. The second training session was conducted with four samples (three orange juices containing 0.5% β-glucan and one orange juice thickened with 0.5% CMC as a reference). A third training session was conducted with four samples (three orange juices containing 0.5–2% β-glucan and one orange juice thickened with 1.3% CMC as a reference). The panelists got feedback of their performance (own rating for each attribute and sample and means of the whole panel) after every training session.

The sensory evaluation of the samples was conducted in eight sessions (including the replicate sessions), each session included four β-glucan beverages and one CMC reference. All samples and the CMC reference were blind-coded. The CMC reference was presented first at each session as a warm-up sample. The β-glucan samples were presented to the panelists in random order. Samples were assessed twice. The data were collected using a computerized data-gathering system (Compusense 5, v. 4.2; CSA, Compusense Inc., Guelph, Canada).

TABLE I
Composition of β-Glucan Preparations

	BG1	BG2	BG3	BG4
Average molecular weight (M_w)	2,000k	2,000k	160k	60k
Carbohydrate (%, db)	58–62	58–62	35	5
Total dietary fiber (%, db)	32–38	32–38	26	50
β-Glucan (%, wb)	13.4	13.7	21.9	34.2
Lipids (%, db)	10–12	10–12	10	16
Proteins (%, db)	21–25	21–25	22	28
Ash (%, db)	4–6	4–6	1	4

Viscosity Measurement

Constant rate measurement of viscosity as a function of shear rate was performed with a StressTech rheometer (CC 25 CCE, Reologica Instruments AB, Sweden) at shear rates of 16.4–157/sec at +20°C. The same samples evaluated by the sensory panel were measured.

Data Analysis

In statistical analysis, the mean values were adjusted with CMC reference ratings (sensory analysis results):

$$X_{ST} = (a - b) + X_{CMCgrand}$$

where X_{ST} = adjusted value; a = panelist's personal rate for single sample and attribute in the particular session; b = panelist's personal rate of CMC sample and attribute in the particular session; and $X_{CMCgrand}$ = mean of the attribute for CMC over all panelists and sessions.

The adjustment was made to eliminate the differences between panelists due to the use of different levels of the scale. This adjustment did not affect the range of scale used by the panelists. Lawless and Heymann (1998) described the situation where panelists agree on the magnitude of the sensory difference between the samples but they used a different part of the scale. With the adjustment, we could eliminate differences between judges but not modify the differences between samples (within subjects). According to Plemmons and Resurreccion (1998), a warm-up sample eliminates first-sample bias and thus increases panelist reliability.

The sensory profile for each beverage was created by calculating the means over the two assessments. For the CMC reference, the sensory profile was created by calculating the means over all 77 assessments. The viscosities of the beverages were determined at various shear rates from 16 to 157/sec. The relationships between sensory evaluation and the instrumental measurements were explored with correlation tests. The data used in the correlation analysis were the means of two replicate samples. CMC reference data were included in the correlation analysis. Two-way analysis of variance (ANOVA) was used for testing possible interactions in the sensory data. Independent variables were concentration (four levels) and β-glucan source (four preparations), dependent variables were all sensory attributes. CMC reference data were excluded from this analysis because the data were included in the adjustment of the other samples and because it did not contain any β-glucan. SPSS software (v. 10.0.5, SPSS Inc. Chicago, IL) was used for the statistical analysis.

RESULTS

Sensory Profiles

Sensory profiles of the beverages differed at the same β-glucan concentrations, depending on the type of β-glucan source (Figs. 1 and 2). The thickness of the beverages especially varied among

TABLE II
Concentration of β-Glucan in Beverage Samples

Sample	Concentration of β-glucan (w/w, β-glucan)
BG1	0.25%
	0.5%
	1.0%
BG2	0.25%
	0.5%
	1.0%
BG3	0.5%
	1.0%
	2.0%
BG4	0.5%
	1.0%
	2.0%
Orange beverage reference sample (does not contain β-glucan)	1.3% CMC

preparations. The more processed preparations (BG3 and BG4) had thinner mouthfeel than the bran-type preparations (BG1 and BG2).

These statistical interactions between β-glucan source (preparation type) and β-glucan concentration in the beverages were tested further. Statistical interactions between the type of β-glucan and concentration were found in two attributes: 1) extensibility of beverage (poured from the spoon) ($F[5, 230] = 2.927$; $P = 0.014$) and 2) thickness of the beverage ($F[5, 230] = 5.853$; $P < 0.001$) (Figs. 3 and 4). In BG1 and BG2 preparations, the increase of extensibility and thickness with concentration was steeper than in BG3 and BG4 preparations. Because of the incomplete data at concentrations of 0.25 and 2.0%, the interactions were also tested using only concentrations of 0.5 and 1.0%; the result was the same.

Sensory thickness (mouth), extensibility (spoon), and sliminess (mouth) were strongly correlated ($r = 0.91–0.95$, $P < 0.001$), which means that these attributes did not vary independently in these beverage samples.

Instrumental and Sensory Measurement Correlations

The viscosities increased remarkably with the increasing concentration of β-glucan in the beverages. There was also large variation between the preparations. For example, at a shear rate 100/sec, the viscosities varied from 4 mPas (BG4 0.5%) to 1,223 mPas (BG2 1.0%) (Table IV). In most samples, the viscosity also showed shear-thinning behavior, with the highest viscosity at the lowest shear rate.

The viscosity was measured at different shear rates. The correlation between sensory thickness, sliminess, and instrumental viscosity was relatively high at all shear rates except at the lowest shear rate of 16/sec (Table V). The correlation was highest at shear rate 100/sec but the differences between shear rates were small. When the thickest beverages (BG1 1% and BG2 1%) were removed from the correlation analysis, the correlation between sensory thickness and instrumental viscosity increased sharply at shear rates of ≥26/sec from $r = 0.71–0.78$ ($P < 0.001$) to $r = 0.91–0.95$ ($P < 0.001$). This may be due to fact that the BG1 and BG2 beverages were probably too thick for the viscosity measurement. In this case, the BG1 1% and BG2 1% beverage samples were barely drinkable; they were closer to a pudding-type of food.

The sour flavor seemed to be masked by the viscosity of the beverage ($r = –0.70$; $P < 0.001$, at a shear rate of 100/sec). The intensity of the orange aroma ($r = –0.49$; $P = 0.005$, at a shear rate of 100/sec) and the total flavor intensity ($r = –0.54$; $P = 0.002$, at a

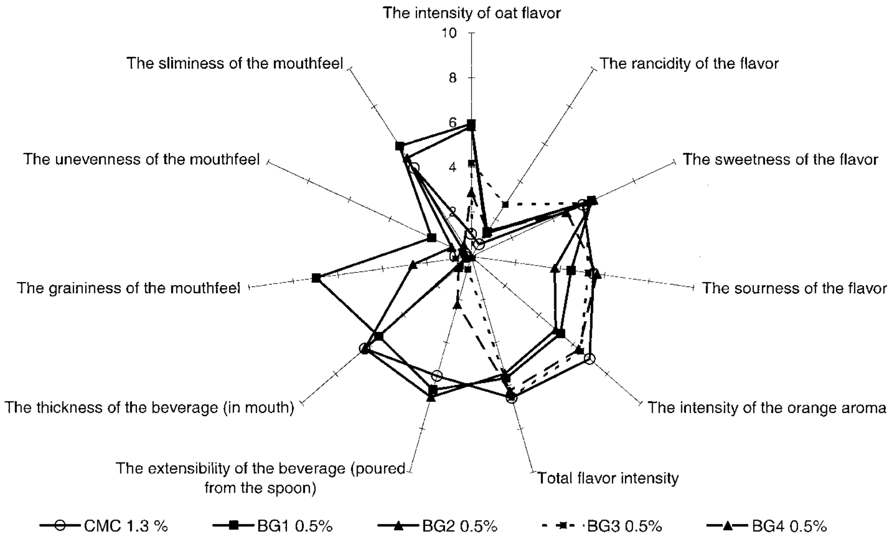

Fig. 1. Sensory profile of the samples at a concentration of 0.5% β-glucan in beverages and reference sample (1.3% CMC).

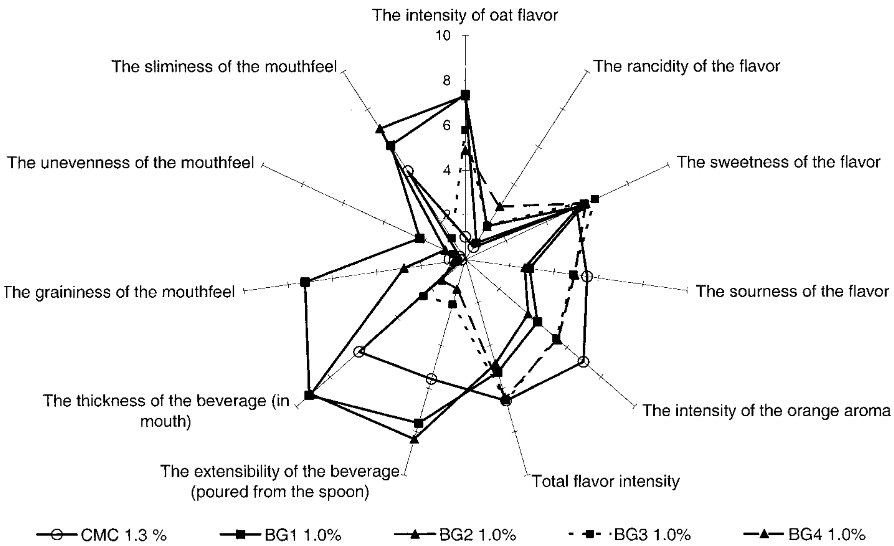

Fig. 2. Sensory profile of samples at a concentration of 1.0% β-glucan in beverages and reference sample (1.3% CMC).

shear rate of 100/sec) also correlated negatively with the instrumental viscosity.

Effect of Molecular Weight of β-Glucan on Sensory Thickness

The correlations between molecular weight ($\log M_w$) and core sensory attributes were calculated at a concentration of 1.0% β-glucan ($n = 8$) because this enabled the comparison of viscosities of different preparations at same concentration of β-glucan. The sensory thickness strongly correlated with the molecular weight of β-glucan ($r = 0.99$; $P < 0.001$), so the high molecular weight β-glucan gave higher viscosity than low molecular weight β-glucan. There was a negative correlation between molecular weight and sour flavor ($r = -0.94$; $P = 0.001$), the intensity of the orange aroma ($r = -0.89$; $P = 0.003$), and total flavor intensity ($r = -0.91$; $P = 0.002$).

DISCUSSION

The molecular weight of β-glucan, and hence the viscosity, is sensitive to processing. Different β-glucan preparations showed different viscosities (both sensory and instrumental) in beverages containing the same amount β-glucan. The correlation between molecular weight and sensory thickness was strong. Low molecular weight β-glucan gave less viscous mouthfeel than high molecular weight β-glucan at the same concentration level. The finding was expected and similar to that already reported by Wood et al (2000). They found a linear relationship between log (concentration × M_w) and log viscosity (at a shear rate of 30/sec). During isolation of β-glucan from the raw material, the molecular weight decreases, which reduces the viscosity of β-glucan. Therefore, low molecular weight β-glucan enables adding physiologically functional amounts of β-glucan to a beverage. However, as high viscosity seems to be crucial for achieving the positive effect of β-glucan on peak blood glucose (Wood et al 1994, 2000), high molecular weight β-glucan is physiologically more effective than low molecular weight β-glucan. The role of molecular weight on the cholesterol-lowering effect of β-glucan is not clear. The viscosity of β-glucan may increase the excretion of cholesterol (Judd et al 1981; Kirby et al 1981), so the high molecular weight and, therefore, the viscosity of β-glucan would be essential in achieving the effect. Beer et al (1997) concluded that processing may decrease the molecular weight of β-glucan. Yet a processed oat product was effective in reducing blood cholesterol levels in the study of Önning et al (1999).

The viscosities of the raw material β-glucan preparations (BG1 and BG2) at a concentration of 0.5% were 305 and 591 mPas, and 250 and 480 mPas at shear rates of 16/sec and 26/sec, respectively. The molecular weight of β-glucan in both preparations was 2,000k. In the study of Dawkins and Nnanna (1995), the results were surprisingly similar. In their study, the viscosity of oat gum at a concentration of 0.5% was ≈250 and 200 mPas at shear rates of 10/sec and 20/sec, respectively. The molecular weight of β-glucan was lower (882k) in that study.

Correlations between sensory texture and instrumental texture have been examined in many studies. The shear rate used in instrumental viscosity measurement may have a significant effect on the

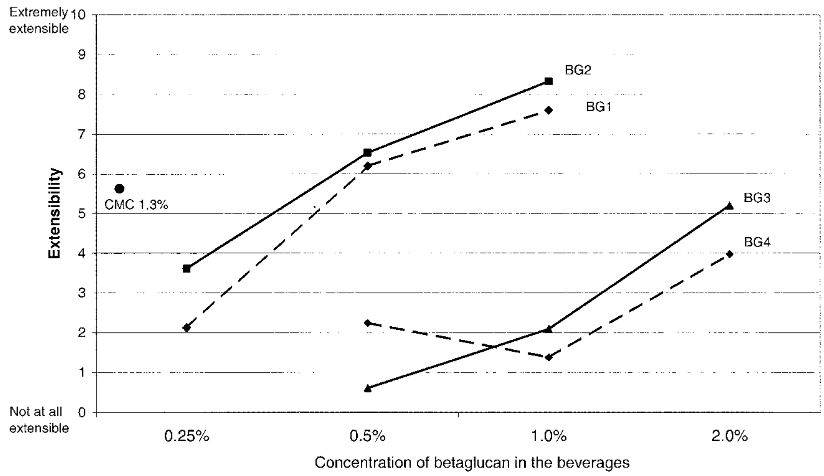

Fig. 3. Extensibility of beverages (poured from the spoon). Circle point represents the extensibility of CMC reference sample.

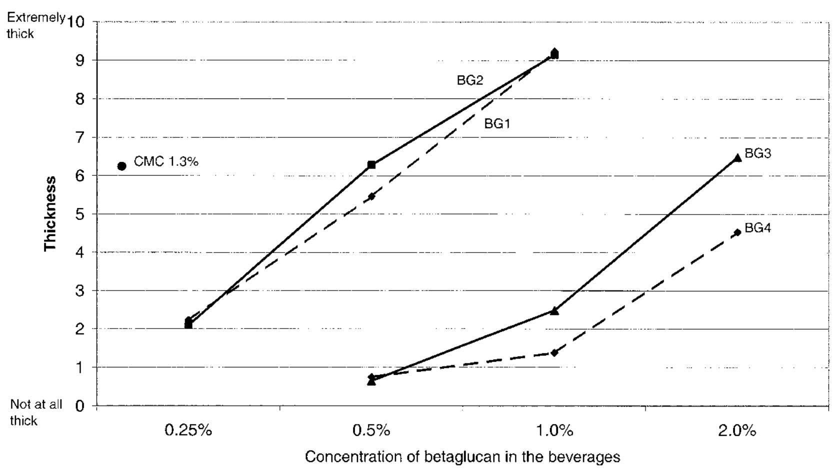

Fig. 4. Thickness of beverages. Circle point represents the thickness of CMC reference sample.

TABLE III
Attributes and Models of the Attributes for Sensory Evaluation

Attribute	Scale 0	Scale 10	Model for Low Level Attribute	Model for High Level Attribute
Flavor				
Intensity of oat flavor	Not at all intense	Extremely intense	Orange juice	Orange juice mixed with oat flakes
Rancidity of the flavor	Not at all rancid	Extremely rancid	Orange juice	Orange juice with rancid oat cookies
Sweetness of the flavor	Not at all sweet	Extremely sweet	Low-sugar orange juice	High-sugar orange juice
Sourness of the flavor	Not at all sour	Extremely sour	Orange juice	Juice with high orange aroma
Intensity of orange aroma	Not at all intense	Extremely intense	Juice with low orange aroma	Juice with high orange aroma
Total flavor intensity	Not at all intense	Extremely intense	No model	No model
Texture				
Extensibility of the beverage (poured from the spoon)	Not at all extensible	Extremely extensible	Ordinary orange fool (thickened with potato starch)	Orange fool, extensible (whipped while boiling)
Thickness of the beverage (in mouth)	Not at all thick	Extremely thick	Orange juice	Thick orange fool (thickened with potato starch)
Graininess of the mouthfeel	Not at all grainy	Extremely grainy	Orange juice	Orange juice with corn starch
Unevenness of mouthfeel	Even	Uneven	Orange fool	Uneven orange fool
Sliminess of the mouthfeel	Not at all slimy	Extremely slimy	Ordinary orange fool (thickened with potato starch)	Slimy orange fool (whipped while boiling)

TABLE IV
Viscosity of Beverages (mPas) at Four Different Shear Rates[a]

		Viscosity at Shear Rates			
Sample		16/sec	26/sec	50/sec	100/sec
CMC	1.3%	329	308	273	233
BG1	0.25%	25	24	22	20
	0.50%	305	250	182	130
	1.0%	2,708	1,925	1,151	698
BG2	0.25%	68	61	51	42
	0.50%	591	480	323	216
	1.0%	4,162	3,043	1,990	1,223
BG3	0.50%	8	8	8	8
	1.0%	33	32	31	30
	2.0%	280	269	254	240
BG4	0.50%	4	4	4	4
	1.0%	9	9	9	9
	2.0%	190	156	122	98

[a] Means of two replicate measurements.

TABLE V
Correlations Between Instrumental and Sensory Measurements[a]

	Viscosity at Shear Rates			
	16/sec	26/sec	50/sec	100/sec
Sourness of flavor	–0.53**	–0.74**	–0.72**	–0.70**
Intensity of orange aroma	–0.29	–0.53**	–0.51**	–0.50**
Total flavor intensity	–0.42*	–0.62**	–0.59**	–0.54**
Thickness (mouth)	0.45*	0.71**	0.73**	0.78**
Sliminess	0.25	0.63**	0.65**	0.70**

[a] *, $P < 0.05$ (2-tailed); **, $P < 0.01$ (2-tailed); $n = 31–32$.

correlation between instrumental and sensory measurements of texture. The high dependence of viscosity on shear rate make comparisons of the results between different studies difficult when the shear rates used were not the same. Positive correlation between sensory and instrumental viscosity in food products similar to ours has been found using various instruments and a range of shear rates. Using a Brookfield viscometer, a high correlation ($r > 0.9$) was found between sensory oral and instrumental viscosity in soymilk yogurt (shear rate 100 rpm) (Buono et al 1990) and in three beverages (shear rate 30 rpm) (Pangborn et al 1978). Good correlations between instrumental and sensory texture measurements (viscosity and thickness) of salad dressing (Wendin and Hall 2001) and lemon pie filling (Hill et al 1995) have also been found.

In our study, viscosity measured at different shear rates had significant but somewhat lower correlations compared with other studies with sensory thickness and sliminess. It is therefore possible to predict sensory thickness based on instrumental values. After removing the thickest beverage samples from the analysis, the correlations increased sharply to $r > 0.9$. Richardson et al (1989) found viscosity at a shear rate of 50/sec had the strongest correlation with sensory sliminess in true solutions and weak gels. This result differs from ours; we found that all the used shear rates >16/sec correlated well with sensory sliminess.

The sourness of the flavor was rated lower in the more viscous beverages than in the less viscous samples. Also, intensity of the orange aroma and the total flavor intensity correlated negatively with the instrumental viscosity. However, as the β-glucan preparations contained only 13–34% β-glucan, it is difficult to separate the pure effect of viscosity from the effect of increasing concentration of other components on the taste. In general, the viscosity of food modifies the perception of tastes (Paulus and Haas 1980; Godshall 1988). Furthermore, composition of the thickener alone has a greater effect on the perception of flavors than the viscosity (Pangborn et al 1973; Mälkki et al 1993). Among the so-called primary tastes, sourness is masked by viscosity (Pangborn et al 1973; Wendin et al 1997).

There has to be sufficient amount of β-glucan in food products to reach the level needed for health effects. FDA allows the health claim for products containing a minimum of 0.75 g of β-glucan per portion. The lowest suggested daily intake of β-glucan for achieving the health effects is 3 g per day, which requires four portions with 0.75 g of β-glucan. Beverage models in this study contained β-glucan from 0.25 g/100 mL to 2 g/100 mL. In compliance with the FDA limit on the amount of β-glucan per portion for using the health claim, the size of one portion would vary from 300 mL (0.25%) to 37.5 mL (2%). With samples BG1 and BG2, it is not possible to go higher than 0.5% β-glucan in the beverage due to technological problems (the beverage gets too thick), but with samples BG3 and BG4, it is possible to go to a concentration of 2% β-glucan in the beverage. Using purified β-glucan fractions also avoids impurities of starch and protein that can cause increased viscosity in foods and consequently cause problems in food processing.

The good viscosity-forming properties make β-glucans potential alternatives as thickening agents in different food applications such as ice creams, sauces, and salad dressings (Wood 1986). Its ability to increase viscosity is lower than, or at the same level as, other thickening agents. Compared with other thickeners at a concentration of 0.5%, oat gum is less viscous than xanthan and guar gum but more viscous than locust bean gum and gum arabic (Dawkins and Nnanna 1995). With shear rate increasing from 1/sec to 20/sec, the differences between gums decreased. Viscosity of β-glucan is not affected by pH level (Dawkins and Nnanna 1995) because β-glucan is a neutral and nonionic polymer. β-Glucan is therefore suitable for a wide range of food products such as acidic beverages. Sucrose seems to increase viscosity of β-glucan (Autio et al 1987; Dawkins and Nnanna 1995). The same result has been reported by

Elfak et al (1977) for guar gum and locust bean gum solutions. To achieve this effect, the sugar concentrations in these studies varied 20–50%. In the beverages of our study, the sugar concentration was 9%. According to Autio et al (1987), NaCl has no effect on the viscosity of β-glucan. Dawkins and Nnanna (1995) found a different result; in their study, high salt concentrations (≥1%) decreased the viscosity. The viscosity of β-glucan temporarily decreases with increased temperature (Autio et al 1987; Dawkins and Nnanna 1995), but the effect of temperature on viscosity of β-glucan is reversible. It would be perhaps possible to add more β-glucan to warm food products, as the product would have decreased sensory thickness during eating or drinking due to increased temperature.

CONCLUSIONS

As expected, the molecular weight of β-glucan had a significant effect on the sensory thickness of beverage samples containing β-glucan. The correlations between instrumental viscosity and perceived sliminess and thickness were good ($r = 0.63–0.78$), and the shear rate had no notable effect on the correlations at shear rates between 26/sec and 100/sec. Technologically, it is possible to prepare a beverage containing a physiologically effective amount of β-glucan from the LMW β-glucan preparations, which are easier to process than HMW β-glucan. However, the relationship between physiological functionality and molecular weight has to be kept in mind. Consumer studies are needed to investigate the acceptability of food products containing β-glucan.

ACKNOWLEDGMENTS

We thank Döhler GmbH, Germany, for providing us the orange beverage base; CEBA AB, Sweden, for β-glucan preparations; and Avena Oat Ingredients, Finland, for β-glucan preparations. This work belongs to the Tailored Technologies for Future Foods (TTFF) research program at VTT Biotechnology. This study has been financially supported by the European Community (EC) within the 5th Framework Programme under the Quality of Life and Management of Living Resources, Key Action 1: Project “Design of foods with improved functionality and superior health effects using cereal betaglucans”, QLRT-2000-00535.

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[Received August 26, 2002. Accepted December 24, 2002.]

PUBLICATION III

The sensory characteristics and rheological properties of soups containing oat and barley *β*-glucan before and after freezing

In: Lebensmittel-Wissenschaft und Technologie 2004.
Vol. 37, pp. 749–761.

ELSEVIER

Lebensm.-Wiss. u.-Technol. 37 (2004) 749–761

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The sensory characteristics and rheological properties of soups containing oat and barley β-glucan before and after freezing

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Received 7 July 2003; accepted 10 February 2004

Abstract

The aim was to study the effect of concentration and molecular weight of two oat and one barley β-glucan preparation on the perceived sensory quality of a ready-to-eat soup prototype before and after freezing. Oat1 was a bran-type preparation containing high molecular weight β-glucan; Oat2 and Barley were more processed and purified preparations with lower molecular weight. Nine soups containing 0.25–2.0 g β-glucan/100 g soup and one reference soup thickened with starch were profiled by a sensory panel and their viscosity and molecular weight of β-glucan was analysed.

Freezing had no notable effects on the sensory quality of the soups. At the same concentration, soups made with the bran-type preparation were more viscous and had higher perceived thickness than soups made with processed, low molecular weight preparations. Barley soups had mainly higher flavour intensities than oat soups. Good correlations were obtained between sensory texture attributes and viscosity ($r=0.70$–0.84; $P\leqslant 0.001$) and moderate correlations between flavour attributes and viscosity ($r=-0.63$–-0.80; $P\leqslant 0.001$). Technologically, β-glucans are feasible thickening agent alternatives in soups. Preparations with lower molecular weight and viscosity are easier to add into a food product in higher quantities, but the role of high molecular weight β-glucan in physiological functionality has to be kept in mind.

Keywords: Beta-glucan; Freezing; Sensory quality; Mouthfeel; Soup

1. Introduction

The mixed linkage (1→3)(1→4)-β-D-glucans (β-glucan) from the endosperm of cereal grains are valuable industrial hydrocolloids and have been shown to be important, physiologically active dietary fibre components (Wood, 2001). β-glucans are water-soluble, linear, high molecular-weight polysaccharides (Autio, Myllymäki, & Mälkki, 1987; Autio, Mälkki, & Virtanen, 1992; Doublier & Wood, 1995). They give viscous, shear thinning solutions even at low concentrations. The viscosity is related to the molecular weight and is strongly dependent on concentration (Autio, 1995; Wood, Beer, & Butler, 2000). Oat β-glucan has been shown to lower elevated blood cholesterol levels (Ripsin et al., 1992; Rimm et al., 1996) and to have a balancing effect on postprandial blood glucose and insulin response (Braaten et al., 1991; Wood et al., 1994). From cereals especially oat and barley are rich in β-glucan. The major difference between oat and barley β-glucan is the size of the molecules, native β-glucan in barley grains is about two thirds of the size of β-glucan in oat (Wood, Weisz, & Mahn, 1991; Autio, 1995; Beer, Wood, & Weisz, 1997a).

Interest in the production and use of isolated cereal β-glucans in foods is due to their potential health benefits. If a product contains at least 0.75 g β-glucan per portion, the Food and Drug Administration (FDA) of USA allows a health claim for oat and oat products concerning the cholesterol-lowering effect of soluble β-glucan fibre and thereby a reduced risk of coronary heart disease (FDA, 1996). The recommended daily intake of β-glucan for achieving the health effects is 3 g/d, corresponding to four portions per day.

Also barley β-glucan has shown to have cholesterol lowering effects in humans (Newman, Newman, &

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doi:10.1016/j.lwt.2004.02.009

Graham, 1989; McIntosh, Whyte, McArthur, & Nestel, 1991; Lupton, Robinson, & Morin, 1994; Ikegami et al., 1996) in hamsters (Kahlon, Chow, Knuckles, & Chiu, 1993; Delaney et al., 2003), rats (Hecker, Meier, Newman, & Newman, 1998) and chicks (Wang, Newman, & Hofer, 1992). Proposed mechanisms of action are, e.g. increased excretion of cholesterol (Lia et al., 1995) and stimulation of the reverse cholesterol transport (Bourdon et al., 1999). In a study with golden hamsters Delaney et al. (2003) concluded that the cholesterol lowering effect of β-glucan is more or less similar whether it is isolated from oat or barley. Barley β-glucan has been shown to lower also postprandial glucose and insulin response in humans (Yokoyama et al., 1997; Hallfrisch & Behall, 2000; Hallfrisch, Schofield, & Behall, 2003).

The good viscosity forming properties make β-glucans potential alternatives as thickening agents in different food applications, e.g. ice creams, sauces and salad dressings (Wood, 1986). Compared to other thickening agents, β-glucan has a lower or equal ability to increase viscosity as xanthan, guar gum, locust bean gum and gum arabic (Dawkins & Nnanna, 1995). To make the consumption of the earlier mentioned four portions of β-glucan feasible, new types of β-glucan containing foods need to be developed, in addition to cereal products where β-glucan is an intrinsic component. One option for these new products are frozen, ready-to-eat foods, as their consumption is growing in general (Dwyer, 1999). Frozen ready-to-eat soups is one possible product category, where β-glucan could be used as thickening agent.

The viscosity of β-glucan also has an effect on the overall sensory quality of the product it is added in. Food products need to have satisfactory sensory properties, because flavour and texture of foods strongly influence repeated choices of novel food products (Arvola, Lähteenmäki, & Tuorila, 1999). We have previously studied the effect of oat β-glucan on the sensory quality of a beverage prototype (Lyly et al., 2003). In this study, it was found that beverages made with the bran-type preparations were more viscous and had higher perceived thickness than beverages made with more processed, small molecular weight preparations.

The elevation of intestinal viscosity due to high molecular weight of β-glucan is important for its physiological effectiveness. High viscosity seems to be crucial for achieving the positive effect of β-glucan on the peak blood glucose (Wood et al., 1994, 2000), which means that high molecular weight β-glucan is physiologically more effective than low molecular weight one. However, a processed oat product (oat milk) was found to be effective in reducing blood cholesterol levels in the study of Önning et al. (1999).

Freezing and storing in a freezer may change the physiological and chemical properties of β-glucan. Especially, high molecular weight β-glucan has been shown to be sensitive to processing; processing may affect solubility and decrease the molecular weight of β-glucan (Beer, Wood, Weisz, & Fillion, 1997b). In the study of Beer et al. (1997b), frozen storage had no effect on the molecular weight of β-glucan in oat bran muffins, but the solubility of β-glucan decreased by 50%. The changes in molecular organisation and crystallinity possibly cause the decrease in solubility (Beer et al., 1997b). Suortti, Johansson, and Autio (2000) also concluded that freezing does not reduce the molecular weight. Solubility determines the viscosity in the gastrointestinal tract, which has an effect on the physiological effectiveness. Heating increases the solubility of β-glucan (Bhatty, 1992; Jaskari et al., 1995), and therefore may affect its physiological effectiveness. As the soups are eaten warm, we expect that the heating of the soup improves the solubility and thus, the effectiveness of β-glucan.

The aim of this study was to compare oat and barley β-glucan as functional ingredients, and to investigate how concentration and molecular weight of two oat and one barley β-glucan preparations affect the perceived sensory quality of ready-to-eat soup prototype before and after freezing, especially regarding thickness.

2. Materials and methods

2.1. β-glucan preparations

Three different β-glucan fractions (Oat1, Oat2 and Barley) were used for preparing the soups. Oat1 was oat bran, rich in β-glucan, produced by dry milling at Finn Cereal (Vantaa, Finland). Oat2 and Barley preparations were soluble β-glucan preparations from CEBA AB (Lund, Sweden), produced by aqueous enzyme-aided extraction. The composition of the three β-glucan preparations is presented in Table 1. β-glucan content of all of the preparations was determined enzymatically by the Megazyme method (McCleary & Codd, 1991). From Oat2 and Barley preparations the total dietary fibre (NMKL, 2003b), ash (NMKL, 1991), total protein (NMKL, 2003a) and lipids (NMKL, 1989) were analysed at an accredited analytical laboratory according to methods defined by the Nordic Committee on Food Analysis NMKL. The content of carbohydrates was calculated by difference when all the other components had been determined.

From Oat1 preparation, dietary fibre was analysed according to the AOAC method (AOAC, 1990). Protein contents were determined by a Kjeldahl method with selenium as digestion catalyst (Digestor DS 2020, Distillation Unit 2200 KJ, Tecator AB, Höganäs,

Table 1
Composition of the β-glucan preparations

	Oat1	Oat2	Barley
Average molecular weight (Mw)[a]	2,000,000	200,000	40,000
Carbohydrate (g/100 g, d.b.)[b]	max 32	15.8	45.2
Total dietary fibre (g/100 g, d.b.)[b]	min 24	33.2	40.7
β-glucan (g/100 g, w.b.)[a]	14.5	19.3	34.5
Lipids (g/100 g, d.b.)[b]	10	19.2	3.7
Proteins (g/100 g, d.b.)[b]	27	30.3	9.9
Ash (g/100 g, d.b.)[b]	n.a.	1.4	0.50

d.b. = dry basis.
w.b. = wet basis.
n.a. = not available.
[a] Analyses performed by authors/VTT Biotechnology.
[b] Suppliers information.

Sweden). Total carbohydrate contents were calculated as difference: 100–(moisture+ash+protein+fat), and lipids according to AOAC method (AOAC, 1995). Also the analysis of Oat1 preparation was performed by an accredited analytical laboratory.

The average molecular weights (Mw) of the preparations were analysed after their isolation and purification by using right angle laser light scattering. The soup samples at concentration 1 g β-glucan/100 g soup were analysed by HPLC-SEC with calcofluor staining (Suortti, 1993) in order to examine the molecular weight during preparation and storage of the soups. As the β-glucan preparations were not contaminated with any other polymeric material eluting in the retention window their Mws could be determined directly by application right angle laser light scattering. In the soups the situation was different as they contained other polymeric compounds, and therefore calcofluor staining was applied. The molecular weight distribution of β-glucan in soup samples was determined on the basis of log Mw versus elution volume calibration curve constructed by isolated β-glucan fractions. The fractions were isolated by semi-preparative HPLC-SEC and their molecular weights were determined by laser light scattering. The validity of calibration curve was later checked by chromatography of β-glucans of various Mws with application of laser light scattering detector; here log Mw versus elution volume calibration curves were obtained and compared to the original curve obtained from isolated β-glucan fractions.

In the reference soup, modified starch (Colflo 67; National Starch, UK) was used as thickening agent. The soup base was frozen roasted bell pepper soup (provided by Findus R & D AB, Bjuv, Sweden). The ingredients of the soup base were water, tomato, onion, roasted red bell pepper, milk powder, tomato puree, carrots, parsnip, vegetable oil, vegetable bouillon, garlic and spices.

Preparation of the soup samples: The soup samples were prepared at VTT Biotechnology laboratory by adding either the previously mentioned modified starch Colflo 67 or β–glucans (and Termamyl-enzyme) into the soup base. The preparation of the samples was done according to Fig. 1. First, the samples were evaluated as 'fresh', which means after the samples were cooled down and reheated again. Reheating was conducted, as also the frozen storage samples were reheated. The water losses during preparation of the samples and reheating were taken into account by adding afterwards the same amount water which was evaporated during heating. Water losses varied between 1.5–4.4% (preparation of the soups) and 1.0–2.8% (reheating of the soups). The remaining quantity of the samples was frozen in a quick-freezer (Model Porkka BC/BF 910; Manufacturer Huurre Group PLC, Finland) and stored for 14–19 days. After the storage period, all samples were evaluated again.

Termamyl 120L Type L (Batch AXN 04325, Novozymes A/S, Denmark) was used to hydrolyse the remaining starch from β–glucans in the Oat1 soups. It was treated prior to use to inactivate possible endogenous β-glucanase by heating 100 ml of 23.5 ml/100 ml Termamyl containing 12 mM $CaCL_2$ in a boiling water bath for 15 min. The solution was sieved through lens cleaning tissue and used at concentration 1 g/100 g soup. The Termamyl enzyme was used only in Oat1 soups, because starch was already removed from Oat2 and Barley preparations during processing.

The β-glucan concentrations in the soups varied from 0.25 g β-glucan/100 g soup up to 2.0 g β-glucan/100 g soup (Table 2). The concentrations were selected based on preliminary trials, where the effect of different concentrations on viscosity was roughly evaluated. The selected concentrations form a geometric progression. The concentration of modified starch in the reference soup sample was 0.8 g modified starch/100 g soup.

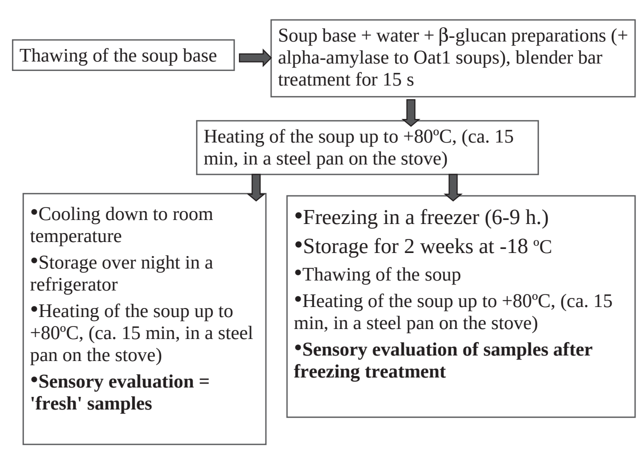

Fig. 1. Preparation of the soup samples.

Table 2
The concentration of β-glucan in the soup samples

Soup sample no.	Preparation used in the soup	Concentration of β-glucan (g β-glucan/100 g soup)	Total dietary fibre content (g fibre/100 g soup)[a]
1.	Oat1	0.25	min 0.41
2.		0.5	min 0.83
3.		1.0	min 1.65
4.	Oat2	0.5	0.86
5.		1.0	1.72
6.		2.0	3.44
7.	Barley	0.5	0.59
8.		1.0	1.18
9.		2.0	2.36
10.	Tomato soup thickened with modified starch (reference sample = warm-up sample) including 0.8 g modified starch/100 g soup.		

[a] Calculated by authors/VTT Biotechnology based on the composition analysis/total dietary fibre values.

2.2. Sensory evaluation

The sensory characteristics of the soups were evaluated using descriptive analysis (Lawless & Heymann, 1998). Attribute intensities were rated on 10-unit graphic intensity scales, verbally anchored from their ends (Table 3). The experienced sensory panel had 20 members, of which four took part in the development of vocabulary, and 10 took part in each evaluation session. The participants per session varied but all of them were selected among the experienced 20 panellists.

The vocabulary (Table 3) was developed in one session. The panellists tasted four different β-glucan soups and described the texture and flavour characteristics. During discussion, altogether nine attributes to describe texture, mouthfeel and flavour of the soups were selected for profiling. For each attribute, except the total flavour intensity and the intensity of possible off-flavour, models were created for training the panel (Table 3). For assessors, detailed instructions on evaluation technique for all attributes were written up for carrying out the evaluations.

The whole panel ($N = 20$) was trained in two training sessions within 5 weeks. During first training session (duration approx. 30 min) the models of the attributes were presented to the panellists to familiarise them with the attributes. Following directly after this, the training session continued with two samples that were evaluated on graphic scales. The second training session was conducted with four samples: three soups containing 0.5–1.0 g β-glucan/100 g soup and one soup thickened with modified starch at concentration 0.8/100 g soup as a reference. The assessors got feedback of their performance, namely their own rating for each attribute and sample and means of the whole panel, after every training session.

Table 3
The attributes and models of the attributes for the sensory evaluation

Attribute	Scale 0 =	Scale 10 =	Model for 'low level of the attribute'	Model for 'high level of the attribute'
Flavour				
The intensity of tomato flavour	Not at all intense	Extremely intense	Tomato soup	Tomato soup with added tomato pure
Saltiness	Not at all salty	Extremely salty	Tomato soup	Tomato soup with added salt (+0.4 g/100 g)
Sharpness	Not at all sharp	Extremely sharp	Tomato soup	Tomato soup with bell pepper and white pepper powder
Total flavour intensity	Not at all intense	Extremely intense	—	—
The intensity of possible off-flavour	Not at all intense	Extremely intense	—	—
Texture				
The extensibility of the soup (poured from the spoon)	Not at all extensible	Extremely extensible	Tomato soup	Tomato soup, thickened with potato starch (whipped while boiling)
The thickness of the soup (in mouth)	Not at all thick	Extremely thick	Tomato juice	Tomato juice (thickened with potato starch)
Powderiness	Not at all powdery	Extremely powdery	Tomato juice	Tomato juice with corn starch
Sliminess	Not at all slimy	Extremely slimy	Tomato juice (thickened with potato starch)	Slimy tomato soup, thickened with potato starch (whipped while boiling)

The sensory evaluation of the samples was carried out in 12 sessions of which six were carried out before and six after 14–19 days storage at -18°C (including the replicate sessions), each session including three β-glucan soups and the reference sample. All samples were blind coded, also the reference sample. The reference sample was presented first at each session as a 'warm up'-sample. The β-glucan samples were presented to the panellists in random order. Samples were assessed twice. The data were collected using computerised data-collecting system (CSA, Computerized Sensory Analysis System, Compusense Inc., Guelph, Canada, Compusense 5, version 4.2).

2.3. Viscosity measurement

Constant rate measurement of viscosity as a function of shear rate was performed with StressTech rheometer (CC 25 CCE, Reologica Instruments AB, Sweden) at shear rates 16.4–157 s^{-1} at $+60^{\circ}$C. All samples evaluated by the sensory panel were measured. Two replicate measurements per sample were conducted, and the average value of the measurements was used in the statistical analysis. Only viscosities measured at shear rate 50 s^{-1} are reported in this article. The shear rate was chosen as it has been shown to correlate with sensory sliminess and thickness in mouth (Richardson, Morris, Ross-Murphy, Taylor, & Dea, 1989).

2.4. Data analysis

For the statistical analyses, sensory ratings were adjusted with reference sample ratings. The adjustment was done to eliminate the possible differences between assessors due to the use of different level of the scale. This adjustment did not affect the range of scale assessors used. Lawless and Heymann (1998) have described the situation where assessors agree on the magnitude of the sensory difference between the samples, but they use different part of the scale. With the adjustment we could eliminate differences between judges, but not modify the differences between samples (within subjects). The reference sample was the first, a 'warm-up' sample in each session. According to Plemmons and Resurreccion (1998), a warm-up sample eliminates the first sample bias and thus increases panellist reliability.

The adjustment was done according the following formula:

$$X_{ST} = (a - b) + X_{Ref.grand},$$

where X_{ST} is the adjusted value, a the assessor's personal rate for single sample and attribute in the particular session, b the assessor's personal rate of reference sample and attribute in the particular session, $X_{Ref.grand}$ the mean of the attribute for reference sample over all assessors and sessions (separate values for fresh and frozen soups)

Due to incompleteness of data, the statistical analyses of sensory ratings were run in several steps. Firstly, the main effects of freezing ($N = 360$) and concentration (within preparations; $N = 120$/each preparation) were tested with separate one-way ANOVAs ($N = 360$). If significant in ANOVA, the differences in means between concentrations were further tested with Tukey's test ($P < 0.05$). Secondly, the possible interactions between effect of freezing (before versus after), source of β-glucan and concentration (0.5, 1.0 or 2 g β-glucan/100 g soup) were tested with the two processed β-glucan preparations (Oat2 and Barley) that formed complete data ($N = 240$). Oat1 preparation was excluded from these analyses due to its strong effects on viscosity that would make unfeasible to prepare real soups at higher level concentrations than 0.5 g β-glucan/100 g soup. Reference sample data were excluded from this analysis, as the data were included in the adjustment of the other samples, and as it did not contain any β-glucan. However, in figures the reference sample means and means of Oat1 preparations are presented to show the sensory qualities of those samples.

As there was practically no difference in the sensory quality of the soups before and after freezing, the sensory profile for each soup in Figs. 2–8 was created by calculating the mean of each attribute over the four sessions (two evaluations before freezing, two after freezing), thus combining the values for fresh and frozen soups. For the reference soup, the sensory profile was calculated over all 12 sessions, combining the values for fresh and frozen soups.

The effect of freezing on the instrumental viscosity at shear rate 50 s^{-1} was analysed with paired samples T-test ($N = 18$) including all β-glucan containing soups in the analysis.

The relationships between sensory characteristics and instrumental viscosity at shear rate 50 s^{-1} were explored with correlation tests. In this analysis all data were included, also data from Oat1 sample and reference sample data. As the viscosity of the samples was measured separately from all the replicate samples evaluated in the sensory analysis, they were included in the analysis as separate samples ($N = 48$).

The correlations between molecular weight (log Mw) and sensory attributes were calculated at β-glucan concentration of 1.0 g β-glucan/100 g soup ($N = 12$), because this enabled the comparison of viscosity of different preparations at the same concentration of β-glucan. In this analysis also data from Oat1 sample was included. Results from soups evaluations before and after freezing were both included in the analysis and also replicate analysis results from all samples evaluated in the sensory analysis, because their molecular weights were analysed separately.

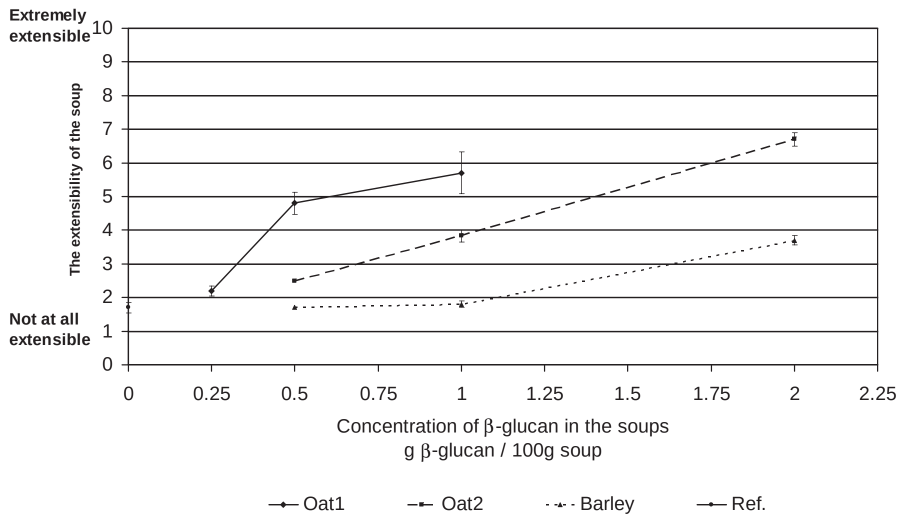

Fig. 2. The extensibility of the soup (means and standard errors).

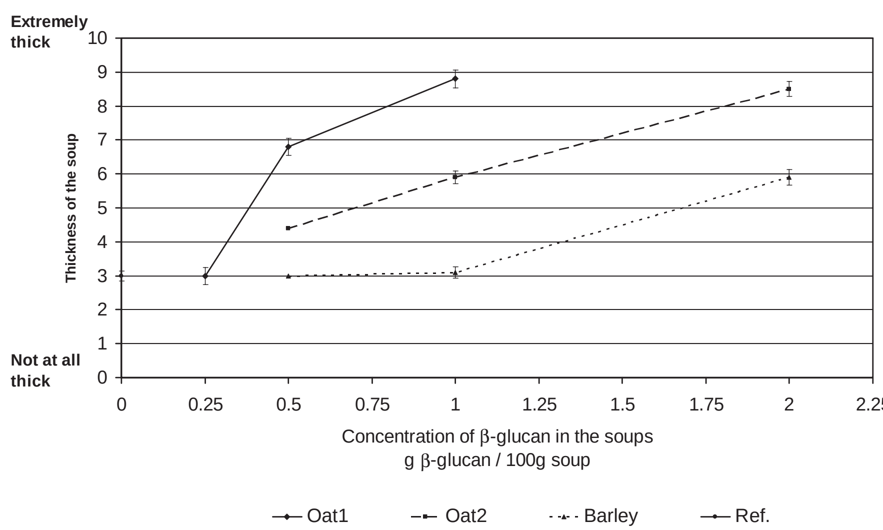

Fig. 3. The thickness of the soup (means and standard errors).

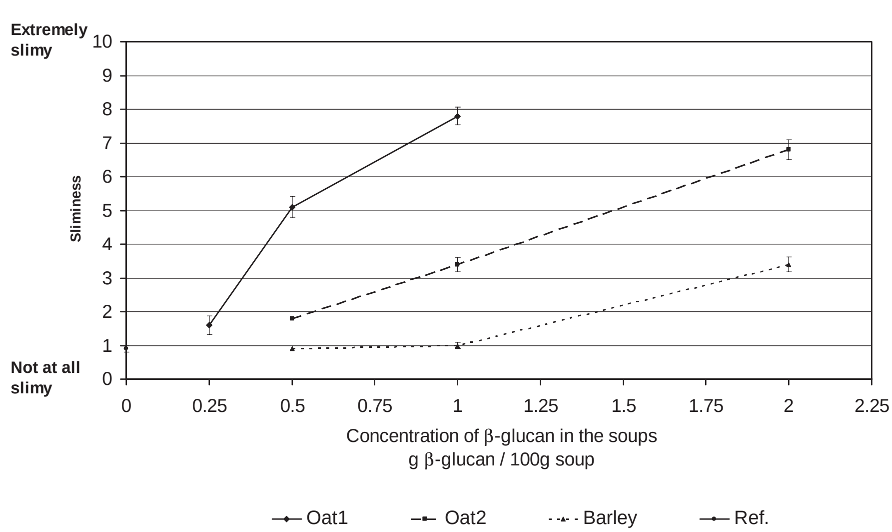

Fig. 4. The sliminess of the soup (means and standard errors).

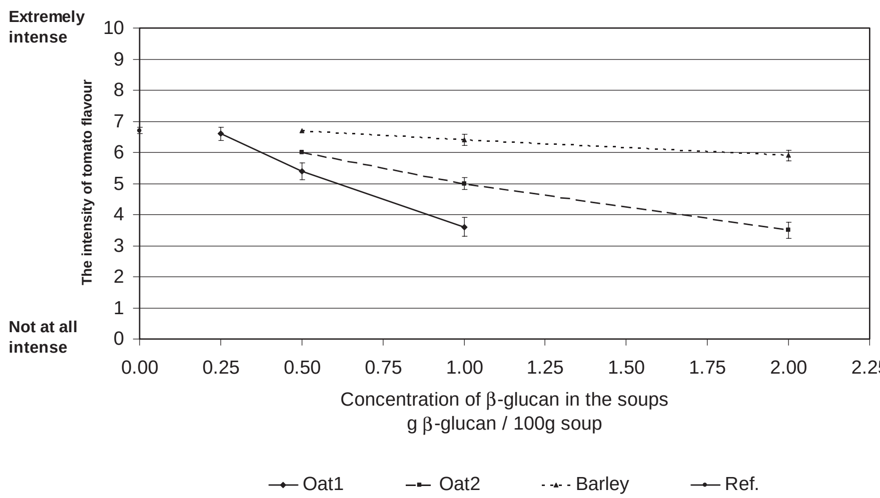

Fig. 5. The intensity of tomato flavour (means and standard errors).

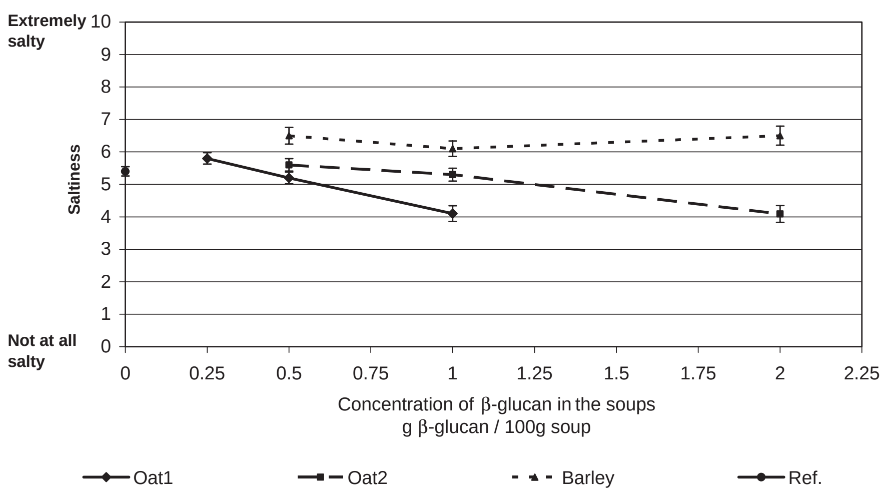

Fig. 6. Saltiness (means and standard errors).

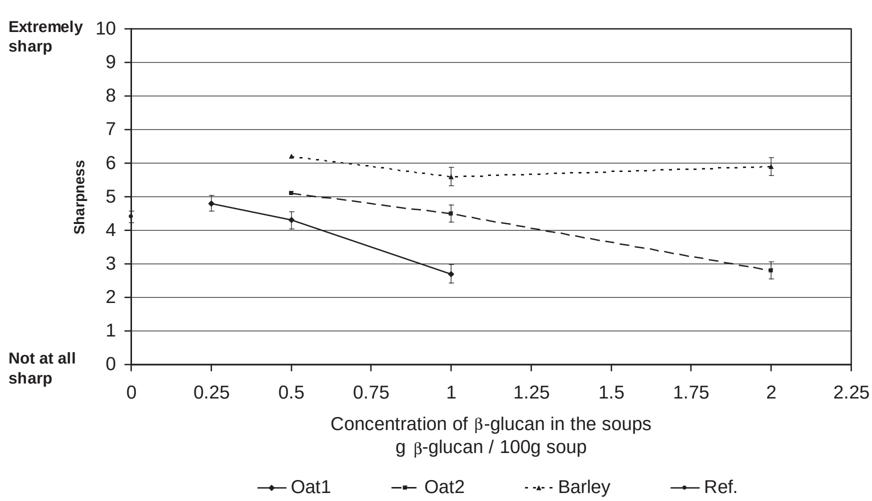

Fig. 7. Sharpness (means and standard errors).

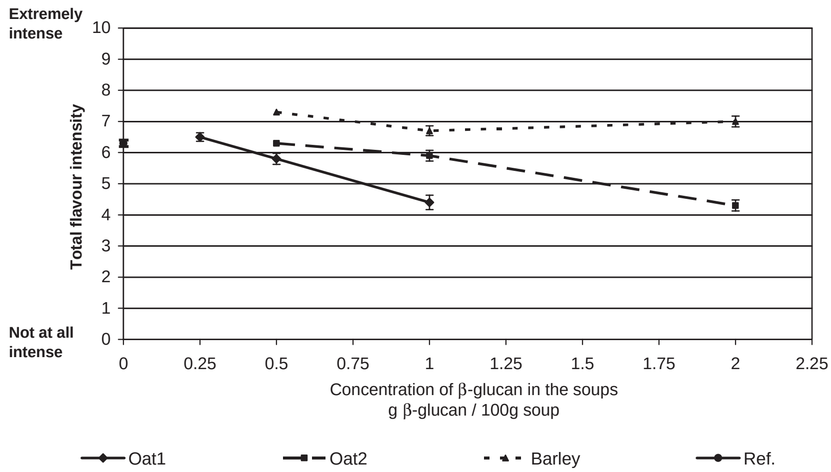

Fig. 8. Total flavour intensity (means and standard errors).

SPSS software (version 11.0.1, SPSS Inc. Chicago, Illinois, USA) was used for the statistical analysis.

3. Results

3.1. The effect of freezing

Freezing had no notable effect on the sensory quality of the soups. Statistically significant difference between fresh and frozen samples were found in the powderiness only [F (1,360) = 5.433; P = 0.020]. Means for powderiness were 2.6 ± 2.1 and 2.1 ± 1.8 before and after freezing, respectively, so the lowering effect of freezing on powderiness was actually very small on scale 0–10, and not important in practice.

Freezing had statistically significant effect on the instrumentally measured viscosity of the β-glucan containing soups [N = 18; t = 2.889; P = 0.01]. At shear rate 50 s^{-1}, the mean viscosity of all β-glucan containing soups over four concentrations was 659 mPa s before freezing and after freezing 451 mPa s, the reduction being about 30%.

3.2. The effect of concentration

In each preparation the increasing concentration of β-glucan affected statistically significantly the sensory quality of the soups (Figs. 2–8). In all β-glucan preparations rising concentration increased extensibility [F(2,120) = 19.4 for Oat1, 41.7 for Oat2, 34.4 for Barley; all P < 0.001], thickness [F(2,120) = 132.8 for Oat1, 97.3 for Oat2, 53.8 for Barley; all P < 0.001], sliminess [F(2,120) = 124.2 for Oat1, 72.0 for Oat2, 39.9 for Barley; all P < 0.001], and off-flavour of the soup [F(2,120) = 9.4 for Oat1, 9.3 for Oat2, 15.0 for Barley; P < 0.001]. At the same time rising concentration decreased intensity of tomato flavour [F(2,120) = 32.1 for Oat1, 24.5 for Oat2; both P < 0.001, 3.3 for Barley; P = 0.039] and total flavour intensity [F(2,120) = 34.2 for Oat1, 30.7 for Oat2; both P < 0.001, 3.4 for Barley; P = 0.036]. Furthermore, in oat-based preparations rising β-glucan concentration lowered the perceived saltiness [F(2,120) = 18.8 for Oat1, 13.0 for Oat2; P < 0.001] and sharpness [F(2,120) = 18.4 for Oat1, 15.2 for Oat2; P < 0.001]. Thus, with Barley preparation the weakening of flavour attributes was smaller than with Oat1 and Oat2 preparations when β-glucan concentration in the soup increased.

3.3. Effect of preparation and concentration

To test whether freezing (before versus after) and increasing concentration (0.5, 1.0 or 2.0 g β-glucan/100 g soup) affect sensory attributes differently in processed β-glucan preparations (Oat2 versus Barley), a three-way ANOVA was carried out. Similar to previous one-way testing, the main significant effects found were concentration of β-glucan (in all attributes P < 0.01, except powderiness which was not significant), source of β-glucan (in all attributes P < 0.01) and freezing in powderiness (P = 0.033) and thickness (P = 0.030). Significant statistical interactions between β-glucan source (i.e. the preparation type) and β-glucan concentration in the soups were found in seven out of nine attributes: 'the intensity of tomato flavour [F(2, 240) = 6.306; P = 0.002], 'saltiness' [F(2, 240) = 6.635; P = 0.002], 'sharpness' [F(2, 240) = 7.299; P = 0.001], 'total flavour intensity' [F(2, 240) = 15.884; P < 0.001], 'the extensibility of the soup (poured from the spoon)' [F(2, 240) = 8.229; P < 0.001], 'the thickness of the soup' [F(2, 240) = 5.522; P = 0.005], and 'sliminess' [F(2, 240) = 10.436; P < 0.001] (Figs. 2–8). This means that the changes in the attribute intensities were dissimilar in different preparations as function of concentration. The thickness of barley soup remained stable when β-glucan concentration increased from 0.5 g β-glucan/100 g soup to 1 g β-glucan/100 g soup, but increased in Oat2 soup in the same concentration range.

Table 4
The viscosity of the soups (mPa s), before and after freezing. Means of two replicate measurements

Samples		Viscosity at shear rate $50\,s^{-1}$	
		Fresh	Frozen
Oat1	0.25 g β-glucan/100 g soup	131	91
	0.50 g β-glucan/100 g soup	347	218
	1.0 g β-glucan/100 g soup	2894	1980
Oat2	0.50 g β-glucan/100 g soup	134	103
	1.0 g β-glucan/100 g soup	290	209
	2.0 g β-glucan/100 g soup	1575	1036
Barley	0.50 g β-glucan/100 g soup	85	58
	1.0 g β-glucan/100 g soup	135	87
	2.0 g β-glucan/100 g soup	343	276
Reference sample	0.8 g starch/100 g soup	110	86

Extensibility and sliminess of the Oat2 soup increased more sharply as a function of concentration than those of the barley soup, whereas intensity of tomato flavour, saltiness, sharpness, and total flavour intensity decreased more steeply in the Oat2 soup as a function of concentration than in the Barley soup.

3.4. Correlations between instrumental and sensory measurements

The increasing concentration of β-glucan increased the viscosity of the soups. There were also large differences between the preparations. For example, at shear rate $50\,s^{-1}$, the viscosity varied from 58 mPa s (Barley frozen 0.5 g β-glucan/100 g soup) to 2894 mPa s (Oat1 fresh 1.0 g β-glucan/100 g soup) (Table 4). In all samples, the viscosity also showed shear-thinning behaviour, having highest viscosity at the lowest shear rate.

Strong negative correlations were found between sensory flavour attributes and instrumental viscosity. Only correlations at shear rate $50\,s^{-1}$ are reported. Instrumental viscosity correlated well with sensory texture attributes; extensibility of the soup ($N = 48$; $r = 0.70$; $P < 0.001$), thickness of the soup ($N = 48$; $r = 0.77$; $P < 0.001$) and sliminess of the soup ($N = 48$; $r = 0.84$; $P < 0.001$). Additionally, the intensity of tomato flavour ($N = 48$; $r = -0.80$; $P < 0.001$), saltiness ($N = 48$; $r = -0.63$; $P < 0.001$), sharpness ($N = 48$; $r = -0.69$; $P < 0.001$), and total flavour intensity ($N = 48$; $r = -0.75$; $P < 0.001$) appeared to be partly masked by the viscosity of the soup.

3.5. Effect of molecular weight of β-glucan on sensory thickness

The molecular weight remained quite stable during freezing. In samples containing 1 g β-glucan/100 g soup, before freezing the molecular weight was 1,100,000 in Oat1 soup, 200,000 in Oat2 and 40 000 in Barley soup. After freezing the molecular weight of Oat2 and Barley soups were the same as before freezing. In Oat1 soup it had changed slightly; the analysis of parallel samples gave results 1,000,000 and 1,400,000, but practically both of the results were close to the original 1,100,000, and most likely the differences were due to sample treatment, not freezing treatment.

The correlations between molecular weight (log Mw) and sensory attributes were calculated at β-glucan concentration of 1.0 g β-glucan/100 g soup ($N = 12$), because this enabled the comparison of viscosity of different preparations at the same concentration of β-glucan. The sensory thickness strongly correlated with the molecular weight of β-glucan ($N = 12$; $r = 0.99$; $P < 0.001$), so the high molecular weight β-glucan gave higher viscosity than low molecular weight β-glucan. There was a negative correlation between molecular weight and the intensity of tomato flavour ($N = 12$; $r = -0.98$; $P = 0.001$), saltiness ($N = 12$; $r = -0.93$; $P = 0.003$), sharpness ($N = 12$; $r = -0.97$; $P < 0.001$), and total flavour intensity ($N = 12$; $r = -0.94$; $P < 0.001$).

4. Discussion

The three different β-glucan preparations gave different viscosity and sensory thickness in soups at the same concentration of β-glucan (Table 4, Fig. 3). Increasing β-glucan concentration had a significant effect on the sensory quality of soups, mainly by increasing the intensity of texture attributes and off-flavour, and by decreasing the intensity of other flavour attributes (Figs. 2–8). In Barley soups the changes were generally milder as a function of concentration compared to oat soups, perhaps due to lower thickness. The viscosity of food is known to modify the perception of tastes (Paulus & Haas, 1980; Godshall, 1988). Furthermore, composition of the thickener in itself has been suggested to have a greater effect on the perception of flavours than just the viscosity (Pangborn, Trabue, & Szczesniak, 1973; Mälkki, Heiniö, & Autio, 1993)

Freezing had no notable effect on the molecular weight of β-glucan or on the sensory quality of the soups, although the freezing treatment was quite severe as the freezing time to −18°C was between 6 and 9 h. The instrumental viscosity of the soups decreased during freezing about 30%, but the reduction was not large enough to be detected in the sensory evaluation. The extractability of β-glucan has been found to decrease during storage in freezer (Beer et al., 1997b), but in the same study the molecular weight remained stable in frozen oat bran muffins. The decline in solubility during frozen storage possibly reflects changes in molecular organisation and crystallinity (Beer et al., 1997b). Heating has been shown to increase the solubility of β-glucan (Bhatty, 1992; Jaskari et al., 1995), and thus may also affect its physiological effectiveness. Therefore, a warm food would be especially suitable for β-glucan enrichment. As the soups are designed to be eaten warm, in this study they were reheated before assessments. This could counteract the solubility-lowering effect of freezing.

As expected, the correlation between molecular weight and sensory thickness was strong and positive. In previous studies, Wood et al. (2000) have found a linear relationship between log (concentration × Mw) and log viscosity. Good correlations were also obtained between sensory texture attributes and viscosity. Previously, we have found a positive correlation ($r = 0.73$, at shear rate 50 s^{-1}) between sensory thickness and instrumental viscosity in β-glucan enriched beverages (Lyly et al., 2003). Positive correlation between sensory and instrumental viscosity in food products similar to ours has been found using various instruments and a range of shear rates. A high correlation ($r > 0.9$) between sensory oral and instrumental viscosity in soymilk yogurt (shear rate 100 rpm, Buono, Setser, Erickson, & Fung, 1990) and in three beverages (shear rate 30 rpm, Pangborn, Gibbs, & Tassan, 1978) was found using Brookfield viscometer. Good correlations between instrumental and sensory texture measurements (viscosity/thickness) of salad dressing (Wendin & Hall, 2001) and lemon pie filling (Hill, Mitchell, & Sherman, 1995) have also been found. In our study, there was a negative correlation between the intensities of flavour attributes and viscosity at different shear rates. However, as the β-glucan preparations contained only 14.5–34.5 g β-glucan/100 g preparation, it is difficult to separate the pure effect of viscosity from the effect of increasing concentration of other components on the taste. Yet it was possible to compare the viscosities of Oat1 and Oat2 soup samples, as the concentration of β-glucan in the preparations was almost the same (14.5 g β-glucan/100 g preparation and 19.3 g β-glucan/100 g preparation, respectively).

The role of molecular weight on the cholesterol lowering effect of β-glucan is not clear. High molecular weight and thereby high viscosity seem to be crucial for the physiological functionality of β-glucan regarding its balancing effect on the peak blood glucose (Wood et al., 1994, 2000). The role of molecular weight on cholesterol-lowering properties is less clear, as also a processed oat product has been found effective in reducing blood cholesterol levels in the study of Önning et al. (1999). Native β-glucan in the grain has a molecular weight of 2–3 million, but the high molecular weight β-glucan is sensitive to processing (Beer, Arrigoni, & Amado, 1996; Beer et al., 1997a, b; Suortti et al., 2000). The giant linear molecules are easily disrupted by enzymatic hydrolysis or high mechanical shear. Even small residual β-glucanase activities of the grain can hydrolyse the β-glucan during isolation process (Autio et al., 1992). Solubility affects viscosity in addition to the molecular weight and total concentration. On one hand, fragmentation of β-glucan and thereby decrease in molecular weight during cooking and processing may enhance the extractability of β-glucan, and therefore the viscosity, but on the other hand, reduced molecular weight consequently alter viscosity (Jaskari et al., 1995; Robertson, Majsak-Newman, Ring, & Selvendran, 1997). In the study of Beer et al. (1997b), baking increased the physiologically extractable amount of β-glucan three- to fourfold but decreased the peak molecular weight by 50% compared to the raw material. They used an in vitro system simulating human digestion in their study. An association between lower molecular weight and increased solubility has been noted in other studies also (Wood et al., 1991).

The amount of β-glucan in food products has to be adequate to reach the level needed for health effects. Soup samples in this study contained β-glucan from 0.25 g β-glucan/100 ml soup to 2 g β-glucan/100 ml soup. In compliance with FDA's limit given to the amount of β-glucan per portion for using the health claim (minimum 0.75 g β-glucan/portion), the size of one portion would vary from 300 ml (0.25 g β-glucan/100 g soup) to 37.5 ml (2 g β-glucan/100 g soup). Concerning soup, a typical portion size could be approximately 350 ml. In this sense, soups could be suitable foods to add β-glucan in. In addition, using β-glucan concentration 1/100 g or higher, it would be possible to include 3 g of β-glucan or even more into one portion (300 g) of soup. With the bran-type preparation Oat1, the maximum practical concentration of β-glucan in the soup was 0.5 g β-glucan/100 g soup due to technological problems (the soup simply gets too thick). With the lower molecular weight preparations Oat2 and Barley, it was possible to add up to 2 g β-glucan/100 g soup. The use of purified β-glucan fractions also makes it possible to avoid the impurities of other components, such as protein and starch, which can increase viscosity in foods and therefore cause problems in food processing.

The results showed that barley β-glucan worked well in this kind of food product regarding its sensory properties. Oat2 and Barley preparations represented both more processed preparation types although the molecular weights were different, which slightly complicates the comparison of oat and barley preparations. Also the concentration of β-glucan of the different preparations used for the soup were different (Table 1), and therefore, the Barley soups made of the preparation with highest concentration of β-glucan contained less additional cereal material than the oat soups.

Due to its originally stronger taste, higher purity of the preparation and lower viscosity, it did not suppress flavour characteristics of the soups as much as did oat preparations (Figs. 5–8). However, the molecular weights of the oat and barley preparations were not the same (Table 1). It would be interesting to compare oat and barley preparations of the same molecular weight. Barley β-glucan has also been found physiologically efficient regarding its cholesterol lowering effect in humans (Newman et al., 1989; McIntosh et al., 1991; Lupton et al., 1994; Ikegami et al., 1996) and in animal studies (Wang et al., 1992; Kahlon et al., 1993; Hecker et al., 1998; Delaney et al., 2003), and it has also favourable effect on blood glucose and insulin responses after meal in humans (Yokoyama et al., 1997; Hallfrisch & Behall 2000; Hallfrisch et al., 2003). In the studies mentioned here, the molecular weight of barley β-glucan preparations was not described, which makes the comparison of physiological effects of oat and barley difficult. However, the interest in using barley as a source of β-glucan in foods is increasing (Bhatty, 1992; Knuckles, Hudson, Chiu, & Sayre, 1997; Hecker et al., 1998).

β-glucans are potential alternatives as thickening agents in different food applications (Wood, 1986) and compared to other thickeners, its ability to increase viscosity is competitive with other thickening agents (Dawkins & Nnanna, 1995). High molecular weight β-glucans are more effective thickening agents than low molecular weight β-glucans as they increase viscosity more at lower concentrations. β-glucan is suitable for a wide range of food products, because as a neutral and non-ionic polymer its viscosity is not affected by pH (Dawkins & Nnanna, 1995). Sodium chloride at concentrations used in food (1–3 g NaCl/100 g food) decreased the viscosity of oat (Dawkins and Nnanna 1995) and barley β-glucan (Gómez, Navarro, Garnier, Horta, & Carbonell, 1997) and has to be taken into account when designing products with β-glucan. The viscosity of β-glucan reversibly decreases with increased temperature (Autio et al., 1987; Dawkins & Nnanna, 1995). In this sense, warm food products would be ideal product alternatives, as the concentration of β-glucan could be higher than in cold food products because the product would have decreased sensory thickness during eating or drinking as a result of increased temperature.

5. Conclusions

The molecular weight and concentration of β-glucan had a significant effect on the sensory thickness of soup, as expected. The sensory characteristics of soups containing barley β-glucan were different compared to oat β-glucans. Freezing had no notable effect on the molecular weight of β-glucan or on the sensory quality of the soups. The correlations between instrumental viscosity and sensory characteristics were good (sensory texture $r = 0.70$–0.84; flavour $r = -0.69$ to -0.80). Technologically, soup is a well-suited product alternative for enrichment with physiologically effective amounts of β-glucan. Using low molecular weight β-glucan preparations (MW$\leqslant$200,000), it is possible to include larger amounts β-glucan into one portion of soup. However, the relationship between molecular weight of β-glucan with respect to physiological functionality has to be kept in mind. Clinical studies are needed to investigate the physiological effects of β-glucan preparations differing in molecular weight and viscosity. Also the consumer acceptability of novel food products containing β-glucan would be essential to investigate.

Acknowledgements

We thank Findus R & D AB, Sweden, for providing us the soup base, and CEBA AB, Sweden and Finn Cereal, Finland, for β-glucan preparations. This work belongs to the Tailored Technologies for Future Foods (TTFF) research program at VTT Biotechnology. This study has been financially supported by the European Community (EC) within the 5th Framework Programme under the Quality of Life and Management of Living resources, Key Action 1: Project "Design of foods with improved functionality and superior health effects using cereal betaglucans", QLRT-2000-00535.

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PUBLICATION IV

Factors influencing consumers' willingness to use beverages and ready-to-eat frozen soups containing oat ß-glucan in Finland, France and Sweden

In: Food Quality and Preference. In press.

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Food Quality and Preference xxx (2006) xxx–xxx

Food Quality and Preference

www.elsevier.com/locate/foodqual

Factors influencing consumers' willingness to use beverages and ready-to-eat frozen soups containing oat β-glucan in Finland, France and Sweden

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Received 24 May 2005; received in revised form 30 September 2005; accepted 13 December 2005

Abstract

Factors affecting consumers' willingness to use beverages and ready-to-eat frozen soups containing oat β-glucan were studied in Finland, France and Sweden ($N = 1157$).

Three beverage or soup samples were presented to each consumer: a reference sample without β-glucan/health claim, a sample containing β-glucan, without claim and a third one with β-glucan and claim (cholesterol or glucose related). Questions about liking, beneficiality, willingness to use and price estimates for purchasing were asked before and after tasting. A trained sensory panel ($N = 11$) also profiled the sensory characteristics of the samples.

Taste of the samples strongly affected the willingness to use them. Health claim gave a significant but small added value to beverages and soups with β-glucan. The price respondents were willing to pay for the beverages and soups containing β-glucan decreased after tasting, regardless of the health claim. No notable effect due to gender or age on the willingness to use products with health claims was found.

Keywords: Consumer; β-Glucan; Willingness to use; Gender; Age; Price

1. Introduction

Functional foods are regarded as an important growth opportunity for the food industry. Fulfilling these expectations requires a great deal of effort from co-operating partners, e.g., researchers, retailers and food ingredient suppliers (Menrad, 2003). Therefore, it is necessary to estimate the interests and probable behaviour of consumers beforehand in order to avoid expensive mistakes in product or concept development.

The interest of the food industry and consumers in dietary fibre is predicted to continue growing (Sloan, 2001). Oat bran seems to be one of the most interesting ingredients due to its already proven health benefits and 'oat drinks' has been mentioned as one of the major trends by Sloan (2001). We wanted to study a potential functional ingredient, oat β-glucan fibre, in two different foods. It has been scientifically proven that oat β-glucan lowers elevated blood cholesterol levels (Ripsin et al., 1992) and has a balancing effect on postprandial blood glucose and insulin response (Braaten et al., 1991; Wood et al., 1994).

Many factors affect consumers' acceptability of foods. Taste and other sensory characteristics of foods occupy a key position. Taste has to be faultless since it strongly influences food choices (Arvola, Lähteenmäki, & Tuorila, 1999), in many cases surpassing health issues (Glanz, Basil, Maibach, Goldberg, & Snyder, 1998; Tepper & Trail, 1998). In addition, Tuorila and Cardello (2002) demonstrated that consumers are not willing to compensate for bad taste with health effects.

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0950-3293/$ - see front matter
doi:10.1016/j.foodqual.2005.12.001

In many cases, however, product information has influenced the perceived benefit and thereby the willingness to use a product. The name of the product, its price and its nutritional benefit information had a significant effect on the intention to buy a fat spread (Bower, Saadat, & Whitten, 2003). Kähkönen, Tuorila, and Rita (1996) found that a low-fat spread was better accepted if consumers received nutrition information before using it.

Product information as such may not in all cases be effective in influencing the acceptability of foods. Attitudes and personal motivation define the relevance of the product information to consumers and determine its efficacy. Attitudes may determine the effect of product information on liking and the likelihood of buying a product (Shepherd, Sparks, Bellier, & Raats, 1991). The sensory ratings of spread labelled as being reduced-fat were more positive if the respondents' attitudes towards reduced-fat spread were positive (Aaron, Mela, & Evans, 1994). In a study by McFarlane and Pliner (1997) on novel foods, general nutrition information increased the willingness to taste novel foods if nutrition was important to the participants. This could also be true with health-related motivational factors: a personal need to prevent illness or to pay attention to one's own health may affect the willingness to use a product with a suitable health claim. The likelihood of the concept of functional foods being accepted increases, if the respondent has an ill family member (Verbeke, 2005). Health problems also motivate individuals to search for specific and relevant nutritional information (Bhaskaran & Hardley, 2002), e.g., those with high blood cholesterol level look for cholesterol-free foods. Information about the fibre content of food increased the likelihood that the elderly intended to purchase the product, as they were concerned about their fibre intake, unlike younger consumers for whom fibre intake was not relevant (Tuorila, Andersson, Martikainen, & Salovaara, 1998). If the end result of using a product is a reduction in disease risk, the motivation to use a product may be strong enough. In a study by Urala and Lähteenmäki (2004), the perceived reward in terms of improved performance and health from using functional foods was the best predictor for a consumer's willingness to use functional foods. In addition, the carrier product type, which is enriched, has an effect on the reactions towards functional foods. In the study by Bech-Larsen and Grunert (2003), functional, enriched spread was perceived as healthier than enriched yoghurt and juice was as the latter products are perceived to be already healthy.

Price cannot be excluded from the factors influencing the willingness to use foods. Price plays a crucial role in the decision of Finnish consumers to purchase functional foods (Ollila, Tuomi-Nurmi, & Immonen, 2004). The role that price played was contradictory to that of Poulsen's (1999) study on functional foods, although he mentioned that a positive attitude towards enriched products would increase the willingness of a consumer to pay a higher price for these products.

The so called traditional demographic variables such as gender and age may also affect the willingness to use a product. In a study by Bower et al. (2003), females, older subjects and consumers with a high health concern had a higher purchase intention for the spread labelled with a proven health benefit. The subjects in this experiment were, however, relatively young (more than half of them were under 25 and the oldest subjects were only 44 years old), which may make it difficult to separate the true effect of age in this study. The proportion of users of plant stanol ester margarine has found to increase with age (Anttolainen et al., 2001) and in Denmark, the elderly had a more positive attitude towards functional foods than young people did (Poulsen, 1999). Older Australian consumers were likely to take preventative actions concerning dietary changes and, in this way, possibly influence their disease risk (Bhaskaran & Hardley, 2002), which could make them more potential users of functional foods.

The objectives of this study were to answer the following questions:

- Does a health claim affect liking for a product, its perceived beneficiality and willingness to use beverages and ready-to-eat soups containing β-glucan?
- How does exposure to the products influence the liking, perceived beneficiality and willingness to use the products?
- Do so called traditional demographic variables, such as country, gender and age affect willingness to use these products?
- Does a personal need to pay attention to one's health affect the willingness to use these products?
- Are consumers willing to pay more for products with health claims?

2. Materials and methods

2.1. Procedure

Consumer data were collected in Finland, France and Sweden during autumn 2003 with the target of 400 participants in each country. Consumers in the three countries were considered to represent different food cultures and have varying views on healthy eating (Margetts, Martinez, Saba, Holm, & Kearney, 1997), perceived benefits of it (Zunft et al., 1997) and perceived need to alter eating habits (Kearney et al., 1997).

In the recruitment situation, the participants were told that the study concentrates on the factors related to food choice on a general level. In Finland and France, respondents answered sample-related questions before tasting in the recruitment situation (*expected* liking, *expected* willingness to use, etc.). Secondly, the participants received three samples of either beverages or soups (Fig. 1) labelled with the ingredient list (Table 1) and instructions for conducting the taste test at home with the same questionnaires to fill in.

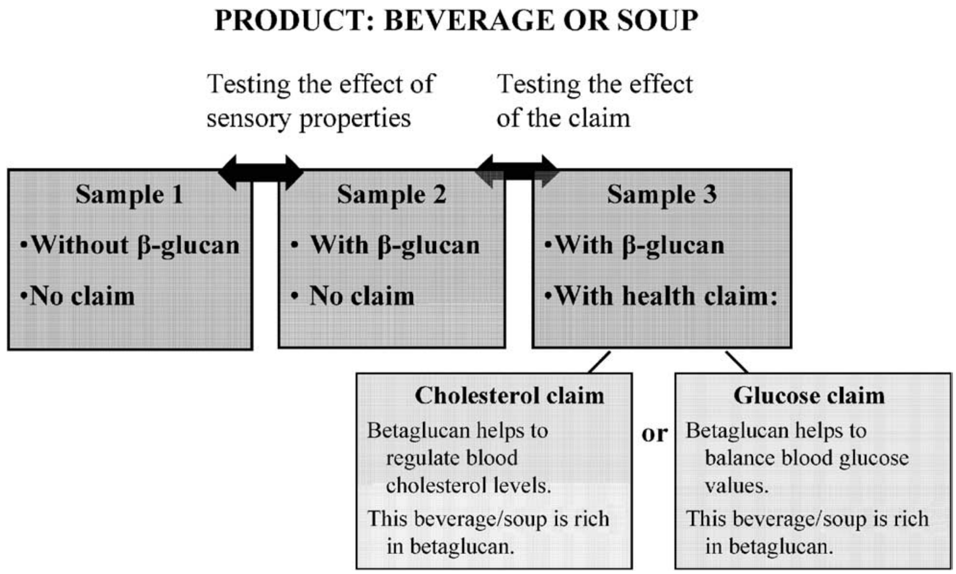

Fig. 1. Sample design.

Table 1
Ingredient list of beverages and soups

	Without β-glucan	With β-glucan
Beverage	Water, fruit juice (apple and pear concentrate), sucrose, fructose, **rice flour**, vegetable fat, preservative (potassium sorbate)	Water, fruit juice (apple and pear concentrate), sucrose, fructose, **oat fraction**, preservative (potassium sorbate)
Soup	Water, carrots, peas, shrimps, tomato, onion, red bell pepper, celeriac, cream, skim milk powder, tomato purée, **maize starch**, maltodextrins, fish bouillon, salt, dill, rape seed oil, shrimp concentrate, white pepper	Water, carrots, peas, shrimps, tomato, onion, red bell pepper, celeriac, cream, skim milk powder, tomato purée, **oat fraction**, maltodextrins, fish bouillon, salt, dill, rape seed oil, shrimp concentrate, white pepper

The difference between the products without and with β-glucan is marked **in bold** in the ingredient lists (it was not highlighted for consumers though).

Participants then sent the completed questionnaires back by mail to the responsible organiser in each country. In Sweden, participants received all samples and questionnaires at the same time at home and they were carefully instructed to fill in the first questionnaire on expected liking, etc., before tasting the samples. In all countries, the respondents received a small reward after completing the study.

2.2. Samples

One of the samples was a reference sample without β-glucan and without a health claim. The two other samples contained β-glucan and they were presented either without a health claim or with a cholesterol- or glucose-related health claim (Fig. 1). With this design, we could test both the effect of sensory properties and the effect of the claim on the acceptance of the products.

The samples used in this study were an apple-pear beverage and a shrimp-dill ready-to-eat frozen soup. In both product categories, there were two different versions: with and without oat β-glucan (Table 1). The amount of vegetable oil in the beverage without β-glucan was very small, 0.65 g/100 g beverage. It was included in the recipe because the energy and nutrient content of the samples had to be as similar as possible, as these same samples were used also in clinical studies (not reported here).

The amount of β-glucan in the beverage and soup samples was 1 g of β-glucan/100 g beverage/soup.

Five members of an experienced sensory panel developed the vocabulary for beverages and soups, which was partly based on earlier studies with β-glucan beverages and soups (Lyly et al., 2003, 2004). The sensory characteristics of the beverages and soups in consumer tests were profiled using descriptive analysis (Lawless & Heymann, 1998). Attribute intensities were rated on 10-unit graphic intensity scales, verbally anchored from their ends. One training session was performed before actual evaluations. The blind coded samples were assessed twice using the experienced sensory panel (11 assessors in each session). The data were collected using computerised data-collecting system (CSA, Computerized Sensory Analysis System, Compusense Inc., Guelph, Canada, Compusense 5, version 4.4).

2.3. Participants

The volunteers for the consumer test were recruited from shopping malls, sports centres, fire stations (to reach males) and from VTT (the Technical Research Centre of Finland) in Finland. In Sweden and France, consumers were recruited from large consumer panels. A total of 613 consumers tasted beverages and 544 consumers soups (Table 2).

The target age of the respondents was 40 years or over. This age group was selected because they are more likely to be potential users of these products compared with younger age groups, who do not yet have an active need to think about ageing and the increasing risk factors of diseases related to it. A total of 4.5% of the respondents were under 40 years old and their age ranged from 17 to 89 (Table 2). The respondents' level of education in France was lower than in Finland and Sweden (Table 2).

In our study 36% of the respondents reported their state of health as reasonably good, 63% as good/excellent and only 1–2% reported their health as poor in all countries. In an European study, quite similarly, 60% of 26–65+ year-old European Union citizens perceived their health as very good/good, 32% as fair and 7.6% as bad/very bad (European Opinion Research Group, 2003). In our study, only the proportion of those reporting their health as poor was slightly smaller than in average in the European Union.

Quite a large proportion of the respondents reported weight control attempts often/constantly (37%) or sometimes (38%) during the past two years.

The motivation to pay attention to health was generally higher among Finnish respondents than French and Swedish respondents (Table 3). The Finnish respondents had a stronger need to pay attention to blood pressure, cholesterol levels, blood glucose levels, gut health, bone health, fibre intake, healthiness of food, and health in general ($F(2,1136) = 6.0–57.6$; $P \leqslant 0.003$). Attention to weight management was equally high in France and Finland, but was slightly lower in Sweden ($F(2,1136) = 7.3$; $P \leqslant 0.001$).

Table 2
Background information of participants (mean values or percentage proportions)

	Finland ($N = 353$)	France ($N = 410$)	Sweden ($N = 394$)	All ($N = 1157$)
Number of respondents				
Beverage group (%)	59	50	50	53
• Cholesterol claim	53	50	50	51
• Glucose claim	47	50	50	49
Soup group (%)	41	50	50	47
• Cholesterol claim	49	50	50	50
• Glucose claim	51	50	50	50
Mean age (years)	57	53	54	55
Range	28–89	35–83	17–78	17–89
% under 40 years	3.1	0.2	10.3	4.5
Gender				
Women (%)	59	49	62	57
Men (%)	41	51	38	43
Education (%)				
Nine years (basic level)	27	49	24	34
College level	55	26	45	41
University level	18	25	31	25
BMI (body mass index: kg/m^2)				
Mean	25	25	25	25

Table 3
The need to pay attention to health; means + (standard deviation)

	Finland	France	Sweden	All countries
Blood pressure	3.8 (2.3)	2.8 (2.0)	3.0 (2.2)	3.1 (2.2)
Cholesterol levels	4.2 (2.0)	3.3 (2.1)	3.1 (2.0)	3.5 (2.1)
Blood glucose levels	3.4 (2.0)	2.7 (1.9)	2.8 (1.9)	2.9 (1.9)
Gut health	3.9 (1.9)	3.2 (2.0)	3.5 (1.9)	3.5 (2.0)
Bone health	4.7 (1.9)	3.6 (2.2)	3.1 (2.0)	3.7 (2.1)
Fibre intake	4.7 (1.8)	3.9 (2.1)	4.2 (1.8)	4.3 (1.9)
Weight	4.6 (2.0)	4.6 (1.9)	4.1 (2.0)	4.5 (2.0)
Healthiness of food	4.8 (1.7)	4.3 (2.1)	4.4 (1.7)	4.5 (1.9)
Health in general	5.5 (1.5)	4.6 (2.0)	4.2 (1.9)	4.7 (1.9)

Scale: 1 = no need at all, 7 = strong need.

2.3.1. Questionnaires

The questionnaires contained questions on liking, the beneficiality of the product for one's own self, willingness to use, a maximum price for trying and for regularly purchasing the product. These questions were asked *before* and *after* tasting the samples. Responses were rated on a 7-point scale (1 = not at all, 7 = extremely much), except the price questions, which were rated on a 100-unit line scale (EUR 0.5–EUR 3.5 for beverages and EUR 1–EUR 6 for soups) with EUR 0.5 and EUR 1 intervals, respectively. For creating the price scales, the manufacturers of the products estimated a realistic price range for these kinds of products in each country. Additionally, about 50% of the lowest and highest price was subtracted from/added to the lowest and highest prices, respectively, to make the scales wide enough.

In addition, respondents filled in a background questionnaire comprising questions on demographic variables, general liking and use frequency of different soups and beverages, health-related questions and attitude questions using the General Health Interest attitude scale (GHI, Roininen, Lähteenmäki, & Tuorila, 1999) and three other scales measuring the attitudes towards functional foods named 'Reward', 'Necessity' and 'Safety' (Urala & Lähteenmäki, 2004). The attitude results are not reported in this paper.

2.4. Data analysis

The sensory profiles for beverages and soups were created by calculating the means over the two assessments. Two-way ANOVA (Analysis of Variance) was used for testing the possible differences between beverage/soup samples. The dependent variables were all sensory attributes and independent variables sample and panellist.

A General Linear Model (GLM) Repeated Measures analysis was used to test the differences between samples in liking, beneficiality and willingness to use the products before and after tasting. The effect of age and gender on willingness to use beverages and soups was also tested with a General Linear Model (GLM) Repeated Measures analysis. If statistically significant differences were found, further analyses were then performed with a GLM multivariate analysis and Tukey's test or a Paired Samples *T*-test. A Pearson correlation, 2-tailed, was used in correlation analyses. SPSS software (version 12.0.1, SPSS Inc. Chicago, IL, USA) was used for the statistical analysis.

All of the results in the following paragraph are statistically significant ($P < 0.05$); therefore, the *P* values are not separately reported for the results from *T*-tests and Tukey's tests.

3. Results

3.1. Sensory profiles of the samples

3.1.1. Beverages

The beverage containing β-glucan was thicker, more extensible, grainier and slimier compared to the beverage without β-glucan (Fig. 2). Moreover, the intensity of the oat flavour was stronger but the sourness, intensity of the fruit aroma and total flavour intensity were weaker in the β-glucan beverage than in the beverage without β-glucan. It is noteworthy that the rancid off-flavour was considerably stronger in the β-glucan beverage (mean 3.8 vs. 0.5 on a scale of 0–10), which indicates that the beverage had an untypical flavour that could be regarded as a product defect.

3.1.2. Soups

The soup containing β-glucan was thicker, more powdery and slimy than the soup without β-glucan (Fig. 3), whereas the intensity of the orange colour, the freshness of the aroma, the intensity of the shrimp aroma, the shrimp flavour, the dill flavour, the freshness of the flavour, the

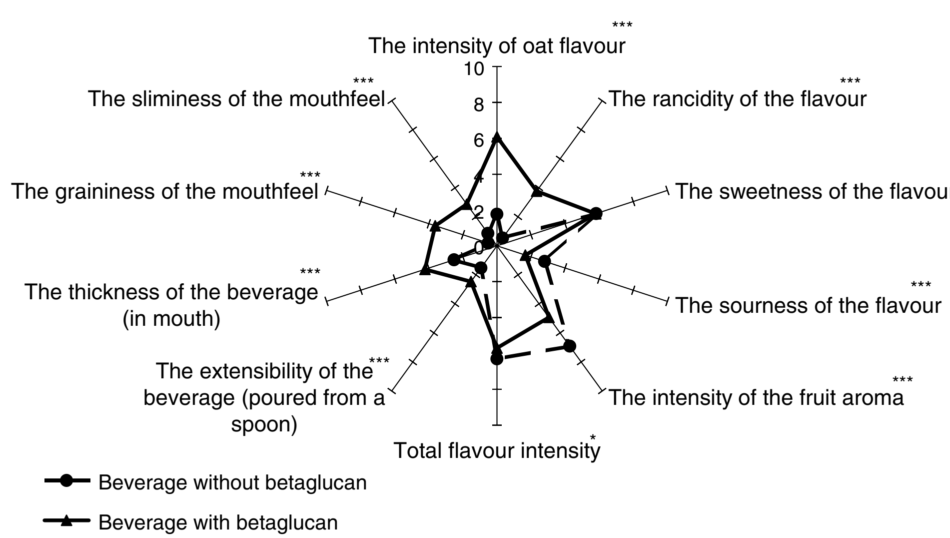

Fig. 2. Sensory profiles of the beverage samples with and without β-glucan. Means of two replicate evaluations ($N = 11$). Statistically significant differences ($(df_1, df_2) = 1, 44$) are marked as ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.

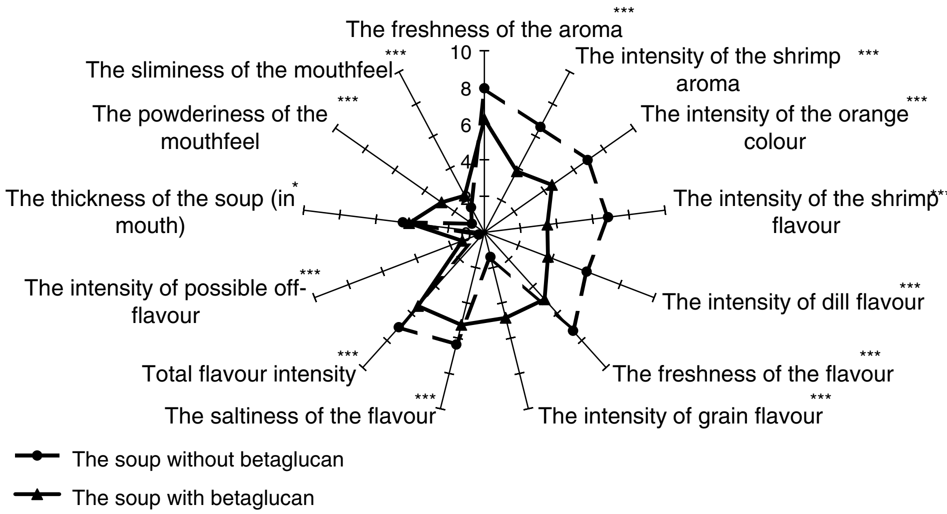

Fig. 3. Sensory profiles of the soup samples with and without β-glucan. Means of two replicate evaluations ($N = 11$). Statistically significant differences ($(df_1, df_2) = 1, 44$) are marked as $^{***}P < 0.001$, $^{**}P < 0.01$, $^{*}P < 0.05$.

saltiness and the total flavour intensity were decreased. The intensity of the grain flavour and the possible off-flavour were increased in the β-glucan soup. The intensity of the off-flavour was, however, only 1.3 on a scale of 0–10.

3.2. *The effect of the health claim and exposure on liking, perceived beneficiality and willingness to use*

Liking, perceived beneficiality and willingness to use all correlated strongly in beverages and soups (Table 4), which means that they were not independent variables. In the following section, however, we present the results separately for each variable.

3.2.1. *Beverages*

The presence of a health claim (either cholesterol- or glucose-related) significantly increased the expected *liking* for the beverage before tasting (Fig. 4a and b, Table 5). After tasting liking for both β-glucan containing samples decreased, despite of the health claims, whereas the liking for the sample without β-glucan increased and it became the best liked after tasting. In the glucose claim subgroup, there were no differences in liking between countries, although differences were observed in the cholesterol claim subgroup; in France, liking of the sample without β-glucan did not change after tasting while it increased in Finland and Sweden. The decrease in liking of β-glucan samples after tasting was steepest in France. However, the differences between countries were mainly caused by the larger difference between samples after tasting in Sweden compared to the other countries and the lowest liking scores of β-glucan samples in France compared to other countries. For that reason, we present the liking for beverages for all of the countries together (Fig. 4a and b).

Beverages with a cholesterol or glucose claim were perceived as significantly more *beneficial* than samples without claim (without or with β-glucan; Fig. 5a and b, Table 5). Although the perceived beneficiality of the β-glucan sample with a health claim decreased after tasting in both claim subgroups, it still remained higher than the β-glucan sample without a claim. In other words, the health claim gave this sample added beneficiality before and after tasting

Table 4
Correlations between liking, willingness to use and perceived beneficiality, and between willingness to use and willingness to pay ($N = 531$–610, all countries together), all rated after tasting

	Liking vs. beneficiality	Liking vs. willingness to use	Beneficiality vs. willingness to use	Willingness to use vs. willingness to pay	
				For trying the product	For regularly buying the product
Beverages					
No β-glucan, no claim	0.67***	0.77***	0.76***	0.40**	0.49**
β-Glucan, no claim	0.70***	0.84***	0.73***	0.44**	0.52**
β-Glucan, claim	0.65***	0.81***	0.72***	0.43**	0.49**
Soups					
No β-glucan, no claim	0.60***	0.77***	0.72***	0.35**	0.43**
β-Glucan, no claim	0.58***	0.81***	0.64***	0.34**	0.44**
β-Glucan, claim	0.63***	0.82***	0.70***	0.40**	0.48**

$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

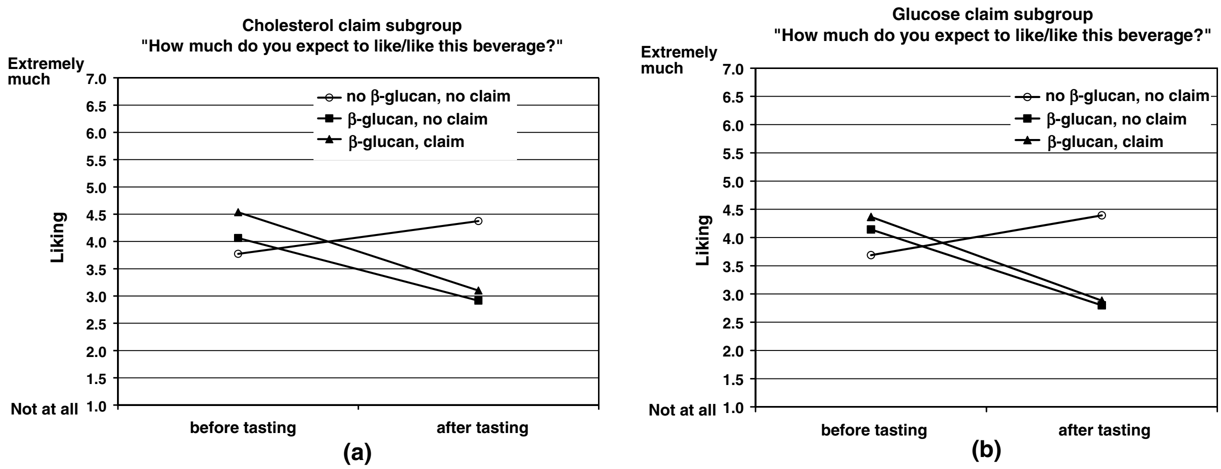

Fig. 4. The liking of beverage samples in cholesterol and glucose claim subgroups. Means are presented over countries.

Table 5
Summary of repeated measures ANOVA on *beverages*

	F rating time ($df_1, df_2 = 1$, 276–284)	F sample ($df_1, df_2 = 2$, 552–568)	F rating time × sample ($df_1, df_2 = 2$, 552–568)	F rating time × sample × country ($df_1, df_2 = 4$, 552–568)	F sample × country ($df_1, df_2 = 4$, 552–568)
Liking					
Cholesterol claim subgroup	67.6***	50.1***	206.1***	1.1	5.4***
Glucose claim subgroup	53.1***	46.1***	191.8***	1.5	0.3
Beneficiality					
Cholesterol claim subgroup	61.6***	96.8***	70.8***	0.16	1.3
Glucose claim subgroup	45.5***	38.6***	57.3***	1.0	2.2
Willingness to use					
Cholesterol claim subgroup	178.2***	42.2***	120.8***	0.97	2.4
Glucose claim subgroup	128.9***	13.3***	100.4***	2.9*	2.5*

Sample means differences between samples with no β-glucan (no health claim), with β-glucan (no health claim), and with β-glucan (with health claim). Rating time means difference between results before and after tasting.
$*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

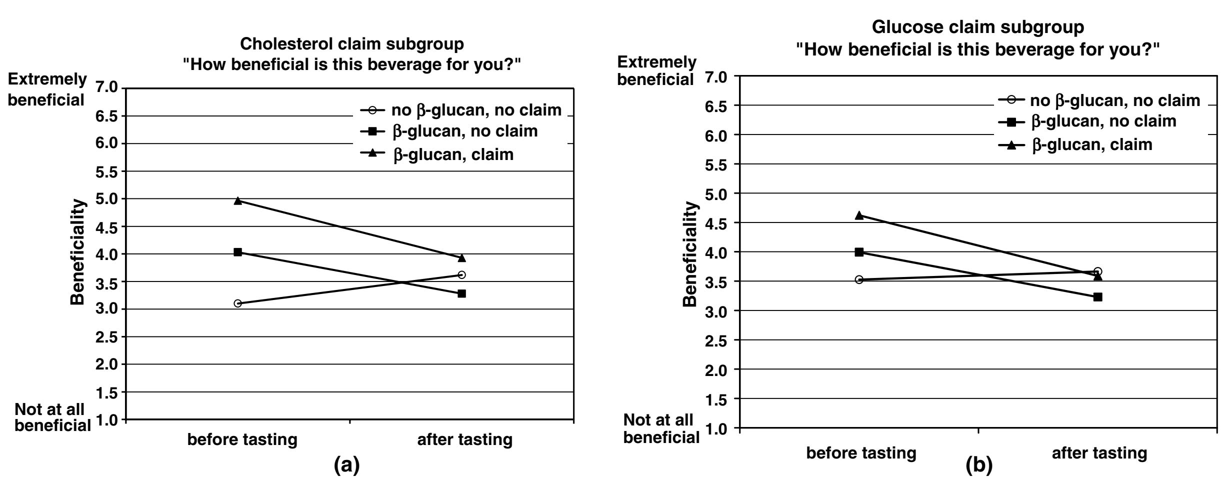

Fig. 5. The perceived beneficiality of beverage samples in cholesterol and glucose claim subgroups. Means are presented over countries.

compared to the sample with the same sensory quality but without the health claim. Respondents in different countries rated the samples similarly in both health claim subgroups.

The presence of a health claim significantly increased *the willingness to use beverages* before the samples were tasted in both health claim subgroups (Fig. 6a and b, Table 5). Before tasting, the willingness to use the sample with a

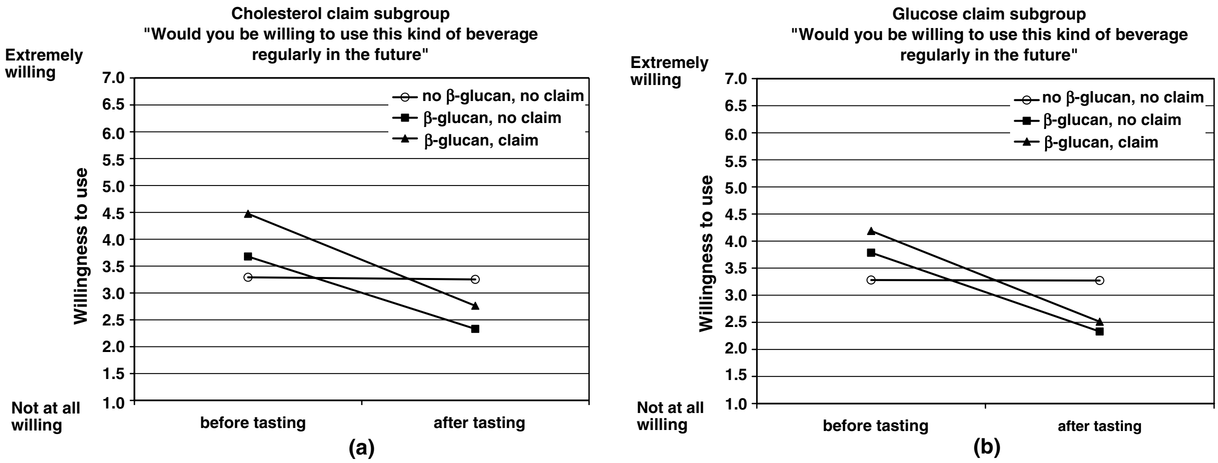

Fig. 6. The willingness to use the beverage samples in cholesterol and glucose claim subgroups. Means are presented over countries.

health claim was higher compared to the samples without a health claim in both the cholesterol and glucose claim groups. The willingness to use, however, decreased once the β-glucan samples with or without a health claim had been tasted, whereas the willingness to use the beverage without β-glucan remained on the same level. This was probably due to a decreased liking caused by the significantly rancid flavour of the β-glucan beverage (Fig. 2). Respondents in both health claim subgroups rated the samples in a quite similar way. Respondents in different countries rated the samples similarly in the cholesterol claim group. In the glucose claim group, there were differences between countries (Table 5); in Sweden, the willingness to use the beverage without β-glucan increased clearly once it had been tasted, while it decreased mildly in Finland and did not change in France. In France, the decrease after tasting in willingness to use samples with β-glucan was steeper than in Finland and Sweden. As the differences between countries were, however, quite weak (Table 5), we present the willingness to use the beverages as means over countries (Fig. 6a and b).

3.2.2. Soups

The presence of a health claim (either cholesterol- or glucose-related) did not notably affect *liking* for the soups before tasting (Fig. 7a and b, Table 6). In the cholesterol claim subgroup, the liking ratings of samples with β-glucan decreased once they had been tasted while liking for the soup without β-glucan mildly increased, being the most liked sample after tasting. In the glucose claim subgroup, the ratings of samples with β-glucan did not change once they had been tasted, although the liking for the sample without β-glucan increased and it was the most liked sample after tasting. All these changes and differences, however, were within 0.3–0.4 points on a scale of 1–7 and thus small. There were no differences for the liking ratings between countries in the glucose claim subgroup. In the cholesterol claim subgroup, the change in liking for sam-

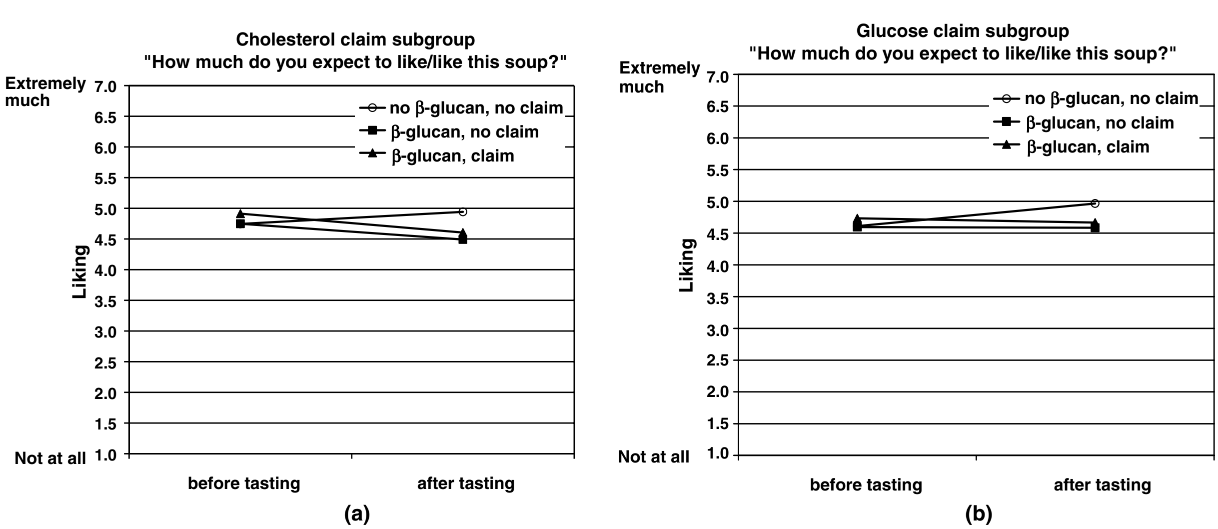

Fig. 7. The liking of soup samples in cholesterol and glucose claim subgroups. Means are presented over countries.

Table 6
Summary of repeated measures ANOVA on *soups*

	F rating time ($df_1, df_2 = 1$, 233–252)	*F* sample ($df_1, df_2 = 2$, 466–504)	*F* rating time × sample ($df_1, df_2 = 2$, 466–504)	*F* rating time × sample × country ($df_1, df_2 = 4$, 466–504)	*F* sample × country ($df_1, df_2 = 4$, 466–504)
Liking					
Cholesterol claim subgroup	2.5	8.7***	10.4***	3.8**	2.7*
Glucose claim subgroup	1.5	5.7**	6.9**	0.6	0.8
Beneficiality					
Cholesterol claim subgroup	15.6***	61.4***	13.2***	1.6	0.3
Glucose claim subgroup	0.6	27.9***	4.7*	0.7	1.2
Willingness to use					
Cholesterol claim subgroup	36.2***	11.7***	17.0***	2.7*	3.8**
Glucose claim subgroup	3.1*	6.4**	7.9***	1.7	1.2

Sample means differences between samples with no β-glucan (no health claim), with β-glucan (no health claim), and with β-glucan (with health claim). Rating time means difference between results before and after tasting.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

ples after tasting changed mildly in Finland and France. However, the differences between samples in liking were within 0.3–0.4 points on a scale of 1–7 and thus small. In Sweden, however, the sample without β-glucan was clearly the most liked after tasting. As these differences were quite weak overall (Table 6), we present all of the countries together (Fig. 7a and b).

The soups with a cholesterol or glucose claim were perceived to be significantly more *beneficial* than the other samples before and after tasting (Fig. 8a and b, Table 6), although the perceived beneficiality of the β-glucan sample with a health claim decreased after tasting. Respondents in different countries rated the samples similarly in both health claim subgroups.

Before tasting, the *willingness to use* the samples with health claims was higher than that of the samples without a health claim, although the difference was very small in the glucose claim subgroup (Fig. 9a and b, Table 6). Once the samples had been tasted, the willingness to use the samples with β-glucan decreased in both claim subgroups whereas it remained on the same level for the sample without β-glucan. Respondents in the glucose claim subgroup rated the samples similarly in different countries. In the cholesterol claim subgroup in Finland and France, all of the samples were ranked equally once they had been tasted, while in Sweden, the sample without β-glucan was ranked the highest once it had been tasted. The statistical interactions between the rating time, sample and country were quite weak (Table 6) mainly due to larger differences between the samples after tasting in Sweden. Thus, in Fig. 9a and b all of the countries and claim subgroups are presented together.

3.3. The effect of age and gender on the willingness to use beverages and soups

We kept both claim subgroups together in these analyses in order to investigate the effect of age and gender on the willingness to use beverages and soups. For this analysis, respondents were first divided into three age groups of equal size using cut-points of 33.3% and 66.7%; 48 years old or less, 49–60 years old and 61 years old or older. There

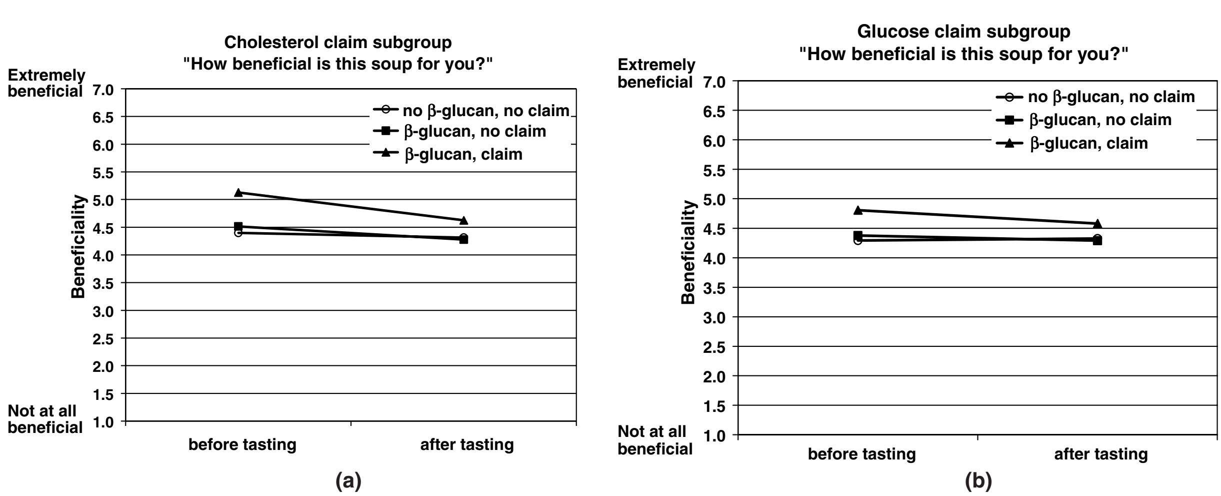

Fig. 8. The perceived beneficiality of soup samples in cholesterol and glucose claim subgroups. Means are presented over countries.

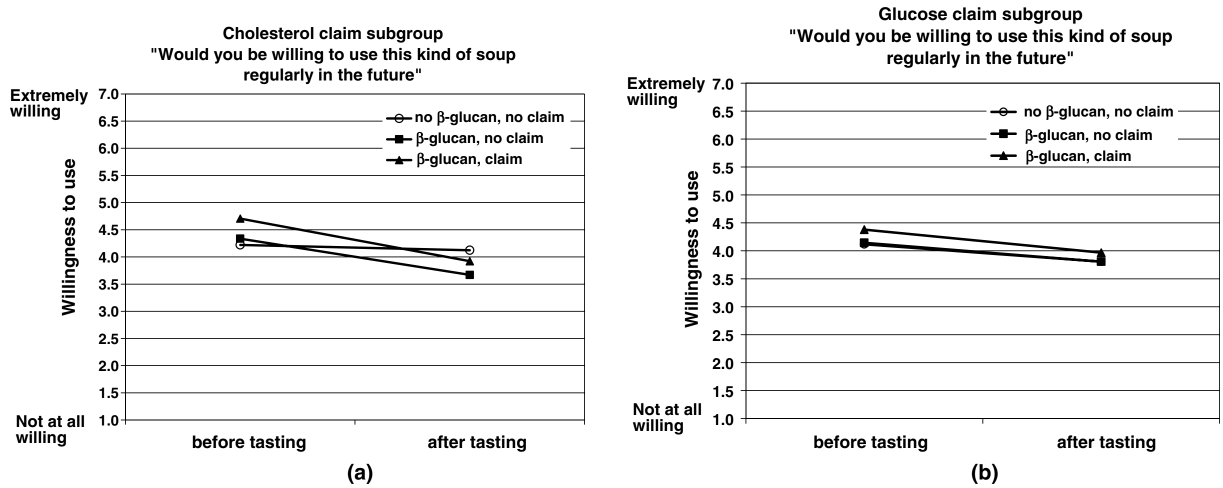

Fig. 9. The willingness to use the soup samples in cholesterol and glucose claim subgroups. Means are presented over countries.

were differences between countries in the ratings of beverage samples in different age groups (sample × country × age group $F(8, 1150) = 2.1$; $P = 0.035$). In further analyses in Finland and France, age did not affect the willingness to use beverage samples. In Sweden, the willingness to use beverage samples was different in the three age groups (sample × age group $F(4, 368) = 3.8$; $P = 0.005$). Moreover, the change in the willingness of older Swedish respondents to use the beverages (rating time × age group $F(2, 184) = 5.0$; $P = 0.008$) before and after tasting was not as steep as that of the younger respondents. In further statistical analyses, Tukey's test showed the two oldest age groups to be more willing to use the β-glucan beverage that had a health claim once they tasted it when compared to the youngest age group ($F(2, 186) = 12.2$; $P < 0.001$). In addition, the respondents in the oldest age group were more willing to use the beverage without β-glucan than the youngest group ($F(2, 86) = 4.5$; $P = 0.012$) was. Age was not found to have any effect on the willingness to use the soups in any of the three countries.

We also tested the possible effect of gender on the willingness to use the beverages and soups with health claims. In beverages, statistically significant interactions for rating time (before and after tasting), sample and gender were found ($F(2, 1150) = 4.5$; $P = 0.011$) but the differences between women and men were very small; the maximum difference was approximately 0.3 points on a scale of 1–7. In soups, statistically significant differences were found for rating time, countries and gender ($F(2, 510) = 3.5$; $P = 0.031$). Further analyses showed that in Finland and France there were no differences in the willingness of men and women to use the soups. In Sweden, statistical interaction was found for the rating time and gender ($F(1, 364) = 4.7$; $P = 0.032$). The decrease in the willingness of women to use the soups with β-glucan once they tasted them was steeper than that of men, and the increase in the willingness of men to use soup without β-glucan once they tasted it was steeper than that of women. These differences and changes were, however, only between 0.1 and 0.3 points on a scale of 1–7.

3.4. The effect of health motivation factors on willingness to use beverages and soups with different health claims

In the background questionnaire, respondents were asked about their personal need to pay attention to their blood cholesterol and glucose levels. The willingness to use β-glucan beverages and soups with health claims was correlated with these ratings. For beverages, quite low but significant correlations were found (Table 7), indicating that those whose need to pay attention to their blood cholesterol or whose glucose values were high were more willing to use the beverage with a cholesterol claim/glucose claim. The correlations were higher after tasting. Those who needed to pay attention to their blood cholesterol were also willing to use beverages with a glucose claim, although not the other way around. No significant correlations were found between the willingness to use soups with health claims and personal health motivation factors.

3.5. Willingness to pay for beverages and soups with health claims

The respondents were asked to rate *before* and *after* tasting *the maximum price for trying and the maximum price for regularly purchasing* the product. Before tasting, respondents were willing to pay the most for beverages and soups with β-glucan and a health claim (Table 8). These prices estimated before tasting decreased after tasting, however, regardless the presence of the claim; the decrease was approximately 20–25% for beverages with β-glucan and/or a health claim and approximately 15% for soups with β-glucan and/or a health claim. In addition, the prices for beverages and soups without β-glucan decreased, although the drop of the prices was much weaker, being roughly 10%. For beverages, the sample without β-glucan

Table 7
Correlation coefficients between the *willingness to use* beverages and soups with health claims before and after tasting and personal health motivation factors ($N = 266–309$)

		Cholesterol claim		Glucose claim	
		Before tasting	After tasting	Before tasting	After tasting
Beverage					
Need to pay attention to	Blood cholesterol levels	0.21**	0.27**	0.15**	0.18**
	Blood glucose levels	0.1	0.16**	0.22**	0.30**
Soup					
Need to pay attention to	Blood cholesterol levels	0.03	0.07	0.02	−0.02
	Blood glucose levels	0.05	0.05	0.02	−0.04

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 8
The maximum prices (€) respondents would be ready to pay for trying and for regularly buying beverages and soups with and without health claim and/or β-glucan

	Trying price (€)			Regular price (€)		
	Before tasting	After tasting	Change %	Before tasting	After tasting	Change %
Beverage, both claims together						
No β-glucan, no claim	1.04 (0.02)	0.99 (0.02)	−4.4	1.04 (0.02)	0.95 (0.02)	−8.6
β-Glucan, no claim	1.09 (0.02)	0.89 (0.02)	−18.7	1.08 (0.02)	0.82 (0.01)	−24.0
β-Glucan, claim	1.20 (0.02)	0.94 (0.02)	−22.1	1.20 (0.02)	0.87 (0.02)	−27.1
Soup, both claims together						
No β-glucan, no claim	2.24 (0.04)	2.01 (0.03)	−10.3	2.31 (0.03)	2.07 (0.03)	−10.1
β-Glucan, no claim	2.23 (0.03)	1.93 (0.03)	−13.8	2.31 (0.03)	1.99 (0.03)	−14.0
β-Glucan, claim	2.35 (0.04)	1.97 (0.03)	−16.1	2.42 (0.03)	2.05 (0.03)	−15.2

Means (SE in brackets) are presented over countries and both claim subgroups. The change in prices is expressed as percentual change.

obtained the highest price ratings after tasting, whereas in soups, the claim helped to maintain the price of the soup that contained β-glucan at the same level with the price of the sample without β-glucan. It seems that the prices estimated before tasting, based on product descriptions, were somewhat unrealistic. For beverages, the decrease in liking due to an off-flavour had a strong effect on the prices respondents were willing to pay.

We also correlated the willingness to use with the willingness to pay for trying/regularly buying the product (Table 4). Significant but moderate correlations were found between the willingness to use and buying price and these correlations were higher for regular purchases than for just sampling the product. Based on these correlations, it seems that the willingness to use is, at some level, related to the willingness to buy. Yet a high willingness to use does not necessarily mean that consumers would accept higher price for buying the product since the correlations were only moderate.

4. Discussion

As expected, the taste of the product played a key role and strongly affected the willingness to use the product. Especially for the beverages containing β-glucan, this was shown very clearly; the perceived beneficiality and a willingness to use them decreased distinctly once the product had been tasted and probably stemmed from a decrease in liking caused by the rancid off-flavour detected by sensory laboratory panel. Oat has a relatively high fat content compared to other cereals and the rancid off-flavour in the β-glucan beverages was most likely caused by lipid oxidation due to unfavourable conditions (Welch, 1995). In the soups the rancid flavour was not detected.

Thus, the expectations did not meet the actual taste and therefore the ratings decreased after tasting. For the soups, the decrease in liking and therefore also in the willingness to use after tasting was only mild. The importance of taste in food choice has been proven in many earlier studies (e.g., Arvola et al., 1999; Glanz et al., 1998; Tepper & Trail, 1998). The results from a laddering study about functional foods showed that taste was more important in Denmark and England than the products' health benefits (Jonas & Beckmann, 1998). Taste was also found to be the most important determinant for use of a nutraceutical product (Cardello & Schutz, 2003).

Health claims had a significant but small positive effect on expected liking in beverages, although once they had been tasted, the liking for beverages with β-glucan decreased and the beverage containing no β-glucan was the best liked. The fact that the faulty taste of the product cannot be compensated with health effects has also established by Tuorila and Cardello (2002). For soups, the health claims did not have a notable effect on liking before or after tasting and in general, all soup samples were liked equally.

As liking is strongly correlated with the willingness to use a product, the willingness to use beverages with β-glucan and their perceived beneficiality decreased once the products had been tasted, although it still remained on a higher level for the beverage with a health claim when compared to the beverage without a claim. Thus, a health claim provided a small, but significant, added value to the beverage with β-glucan.

For soups, a corresponding effect was noted as the health claims had a positive effect on their perceived beneficiality, mainly before tasting. The decrease of beneficiality and willingness to use soups with claims after tasting was very mild compared to the beverages, mostly because of the better accepted sensory quality of them. In addition, it appears that the health claims in soups had a different effect than the effect they had in beverages, which is discussed later.

The differences between countries in liking and willingness to use were quite small; for beneficiality, there were no differences amongst the countries. French consumers seemed to be more critical in liking and willingness to use the beverage with β-glucan. This finding is logical in light of the results found by Rozin, Fischler, Imada, Sarubin, and Wrezesniewski (1999); among Belgians, French, Americans and Japanese consumers, they discovered that French consumers seek the most pleasure from food and least favour fat-/salt-reduced diets.

The effect of age on the willingness to use was only seen in Sweden amongst the consumers tasting beverages. The youngest consumer group was clearly the least willing to use beverages with health claims. Naturally, aged consumers are more potentially users of functional foods (Bower et al., 2003; Poulsen, 1999) as they are more likely to have personal or other experience with health problems, such as high cholesterol levels. Younger consumers are not yet motivated to improve or maintain their health with functional foods. Interestingly, this effect was only seen in Sweden and only in beverages, not in soups. It must, however, be kept in mind that our respondents were mainly older than 40, with the mean age being more than 50. It could be that Swedish consumers pay special attention to their health later than French and Finnish consumers do, who already start to focus on these matters in their 40s or at a younger age.

No major significant differences between the willingness of men and women to use the beverages or soups with health claims were found. This finding is contradictory to those of other studies that state that women are generally more likely to be potential users of functional foods (Bower et al., 2003; Poulsen, 1999) and to more likely have a higher purchase intent for a spread with a health benefit label (Bower et al., 2003). On the other hand, this is similar to Verbeke (2005) finding as he did not find gender to determine the acceptance of functional food concept. In addition, de Jong, Ocké, Branderhorst, and Friele (2003) did not find differences between the use of cholesterol-lowering margarine between men and women. On the other hand, in a study by Anttolainen et al. (2001), men more commonly used plant sterol margarine than women did. One possible explanation could be that women are not as interested in cholesterol-lowering products as men more often have elevated serum cholesterol values and suffer from more often from coronary heart disease.

A weak but significant association was found between personal health motivation factors and the willingness to use beverages with health claims. If consumers had a personal perceived need to pay attention to blood cholesterol or blood glucose values, they were more willing to use beverages with cholesterol or glucose claims, especially after tasting the product. Similarly, Tuorila et al. (1998) have found a connection between how concerned consumers are about their fibre intake and their acceptance of snack foods labelled ‘high fibre’. Interestingly, these kinds of significant relations were not found at all for soups. In addition, age did not have any effect, either, and soups were generally rated differently from beverages, as described earlier. Hence, the product type itself has an important effect on the attitudes towards the health claim attached to it. As found by Urala and Lähteenmäki (2003), functional foods are perceived to be a member of a particular product category (e.g., beverages) and not as a homogenous group over different product categories. De Jong et al. (2003) concluded that the use of functional foods or supplements is dependent on the type of product; therefore, consumer characteristics cannot be generalised over different food or supplement groups. Our study indicates that the results are different and dependent on the product itself, a beverage or a soup. One possible additional explanatory factor could also be the differences in the acceptance/liking of beverages and soups with β-glucan. Because β-glucan beverages generally had a lower level of pleasantness than β-glucan soups, additional motivation to use them was required to compensate for their unfavourable taste. The same does not hold true for soups, however, as their taste was acceptable and they were easy to like. Consequently, health motivation factors only correlated with β-glucan beverages.

Some of the differences in the responses that were obtained for soups and beverages can easily be explained by the more accepted sensory quality of the soup. This does not, however, explain the differences in expectations (the situation before tasting) where beverages with health claims were rated to have higher additional values than soups. Kähkönen, Tuorila, and Hyvönen (1995) suggested in the discussion of their results that, in Finland, soup is considered to be a low-fat food. Generalising this finding to other countries could partly explain the results of why health claims provided so little added value to soups. Low-fat foods are often considered to be healthy (Oakes, 2003) and a health claim cannot easily make this kind of product more attractive. Bech-Larsen and Grunert (2003) found in their study that yoghurt and juice were perceived to be healthy as such and these products did not benefit from enrichment with functional components. In a study by Levy, Derby, and Roe (1997), yoghurt as a product did not benefit from a calcium and osteoporosis health claim, as this information was already recognised by the respondents; therefore it did not provide added value information and did not consequently have any effect on consumers. Thus, the nutritional quality of the carrier product primarily determines the perceived healthiness of the food, and the effect of health claims and functional ingredients is less important (Bech-Larsen & Grunert, 2003).

The trying and regularly buying prices respondents estimated before tasting were rather unrealistic as the decrease after tasting was rather notable, particularly for beverages with β-glucan, although the faulty sensory quality of the beverage definitely had an influence on this. The decrease in prices was steepest for beverages with a health claim. Because of the health claim, consumers expected more from the product and, as the consumers were willing to pay more from the health effect, they respectively expected reasonable product quality to offset the higher price. In the study by Jonas and Beckmann (1998), Danish respondents were not willing to pay more for a product with functional benefits. Among Finnish consumers, the price of functional foods plays an important role in buying decisions (Ollila et al., 2004). A high price could be an obstacle to buy a product, although it did not necessarily prevent those consumers who perceived a special health-related need to use functional foods and believed that these products are effective from buying it. In our study, the moderate correlations between the willingness to use and willingness to pay indicate some link between these two variables but also differences in reactions to these factors. A higher price is not necessarily accepted, even though the willingness of consumers to use a product would be high.

5. Conclusions

The taste of products had a strong influence on the willingness of a consumer to use them. Health claims provided additional value to beverages and soups, although the sensory quality of the products was more important. Soups received different responses than beverages did, partly due to differences in sensory quality, but also partly due to the crucial role that the carrier product type itself plays. Age or gender did not notably affect the willingness to use products with health claims. The product quality has to be faultless for the additional value provided by health effects to exist, thus increasing the willingness of consumers to use the products and pay reasonable prices for buying them.

Acknowledgements

We would like to thank Findus R&D AB, Sweden, for providing us with the soup samples and CEBA AB, Sweden for providing us with the beverage samples. We would like to thank Plateforme Alimentec/Les Maisons du Goût in France and Findus R&D AB in Sweden for performing the consumer study in France and Sweden. This work belongs to the Tailored Technologies for Future Foods (TTFF) research program at VTT Biotechnology. This study has been financially supported by the European Community (EC) within the 5th Framework Programme under the Quality of Life and Management of Living resources, Key Action 1: Project "Design of foods with improved functionality and superior health effects using cereal betaglucans", QLRT-2000-00535.

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Published by

Series title, number and report code of publication

VTT Publications 594
VTT–PUBS–594

Author(s)
Lyly, Marika

Title

Added β-glucan as a source of fibre for consumers

Abstract

The intake of dietary fibre does not currently meet the recommendations in many Western countries, and it is important to find new ways to increase its intake. β-glucan is a good option for fibre enrichment, because of its proven capability to reduce elevated blood cholesterol levels and balance blood glucose and insulin response after meals.

The general aim of this thesis was to investigate whether providing foods enriched with β-glucan would be a feasible strategy for improving consumers' dietary fibre intake.

The results showed that Finnish respondents considered dietary fibre important for their health, although it was not spontaneously mentioned as an element of a health-promoting diet. A group of respondents overestimated their dietary fibre intake compared to their actual intake. This misperception can be an obstacle to improving the quality of the diet.

Adding oat and barley β-glucan into beverages and ready-to-eat soups affected their sensory characteristics by making them thicker and suppressing some flavour attributes with increasing concentrations of β-glucan. Low molecular weight β-glucan was easier to add into products at higher concentrations compared to high molecular weight β-glucan as regards the lower viscosity-producing capability and thus more feasible sensory characteristics. However, attention should also be paid to the importance of the high molecular weight of β-glucan in terms of its physiological efficacy. Freezing did not affect the sensory characteristics of soups containing β-glucan.

Connecting a health claim to beverages and soups with added β-glucan increased their perceived benefit value, but liking for the products was the strongest determinant for the willingness to use them. It does not seem likely that consumers would be ready to pay much extra for functional beverages and soups.

In conclusion, the present study demonstrated that Finnish consumers perceive fibre to be important for their health. Beverages and soups with added β-glucan were feasible regarding their sensory properties and thus would be potential carrier products for added β-glucan. Liking for the products was the most important factor affecting the consumers' willingness to use these foods.

Keywords
dietary fibres, β-glucans, fibre enrichment, consumer acceptance, functional food, beverages, soups, sensory quality, healthy diet

ISBN
951–38–6700–5 (soft back ed.)
951–38–6701–3 (URL: http://www.vtt.fi/publications/index.jsp)

Series title and ISSN
VTT Publications
1235–0621 (soft back ed.)
1455–0849 (URL: http://www.vtt.fi/publications/index.jsp)

Project number

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VTT PUBLICATIONS 594 Added ß-glucan as a source of fibre for consumers

The intake of dietary fibre does not currently meet the recommendations in many Western countries, and it is important to find new ways to increase its intake. The aim of this thesis was to investigate whether providing foods enriched with ß-glucan would be a feasible strategy for improving consumers' dietary fibre intake regarding the sensory properties and consumer acceptance of these foods. ß-glucan is a good option for fibre enrichment of foods because of its proven capability to reduce elevated blood cholesterol levels and to balance blood glucose and insulin response after meals.

The study showed that dietary fibre had a positive image among Finnish respondents and it was considered important for health. Beverages and soups with added ß-glucan were acceptable regarding their sensory characteristics, thus being feasible carrier products for ß-glucan and providing a possible non-traditional source of dietary fibre. Liking for the products with added ß-glucan was the most important factor affecting the willingness to use them, indicating that the sensory quality of products with added dietary fibre with health benefits has to be acceptable, only then consumers are willing to buy them.

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ISBN 951-38-6700-5 (soft back ed.)
ISSN 1235-0621 (soft back ed.)

ISBN 951-38-6701-3 (URL: http://www.vtt.fi/inf/pdf/)
ISSN 1455-0849 (URL: http://www.vtt.fi/inf/pdf/)

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