New applications of fibres in foods: Addition to fishery products

Borderías, A.J.[(*)], Sánchez-Alonso I. and Pérez-Mateos, M.

Instituto del Frío (CSIC)

C/ José Antonio Novais, 10

28040 Madrid

Tel. 34- 91 549 23 00

Fax. 34- 91 549 36 27

(*) jborderias@if.csic.es

Abstract

Seafoods possess high nutritional value and moreover offer functional properties. However, fish products do not contain fibre. Fibre is an essential compound in the diet, which has health benefit effects in certain disorders. At the same time, dietary fibres can be an effective tool in seafood processing for improving functional properties such as water binding, gelling, etc. This paper offers a general view of the role of dietary fibres in a food system and discusses the technological and functional roles of different types of fibres of vegetable origin (cereal, fruits) and animal origin (chitosan), with different characteristics, when they are used as ingredients in the development of restructured fish products.

WHAT IS DIETARY FIBRE?

The way food is perceived in developed countries has changed in the last twenty years, bringing new life to the Hippocratic principle "*Let food be thy medicine and medicine be thy food*" and following the tradition in oriental cultures of attributing curative and "therapeutic" properties to foods. The upshot has been awareness of the need to use diet as a means of staying healthy. This tendency has brought with it the concept of functional

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foods, in which the stress has shifted from seeking to ensure food supplies to identifying the potentialities of foods as promoters of physical and mental health and seeking to reduce the risk of chronic disorders. The notion of functionality is today the main driving force behind the development of new food products (Jiménez-Colmenero, 2004) and was instrumental in the incorporation of the groups of functional compounds identified by Goldberg (1994): dietary fibre, oligosaccharides, sugars/alcohols, amino acids, peptides and proteins, glucosides, alcohols, isoprenoid lipids and vitamins, colines, acidolactic bacteria, minerals, non-saturated fatty acids and other products like antioxidants and phytochemical compounds.

Unlike other nutrients, fibre is not attacked by the enzymes of the stomach and small intestine and therefore reaches the colon undegraded. Traditionally, dietary fibre has been defined as "that fraction of the edible part of plants or their extracts, or synthetic analogues that are resistant to the digestion and absorption in the small intestine, usually with complete or partial fermentation in the large intestine" (Prosky, 2001). The term "dietary fibre" includes polysaccharides, oligosaccharides, lignin and other associated substances. Nowadays, however**,** the definition is broader, including not only non edible parts of vegetables but also fibres of animal origin such as chitosans, which are derived from the chitin contained in the exoskeletons of crustaceans and squid pens and whose molecular structure is similar to that of plant cellulose.

According to the American Dietetic Association, the current recommended fibre intakes for adults range from 25 to 30 g/day or 10 to 13 g/1000 Kcal, and the insoluble/soluble ratio should be 3:1. In Europe consumption currently stands at 20 g/person/day, but in developing countries the range is 60-120 g/day. Fibre as a food ingredient may be considered to possess two kinds of properties: a) technological functionality and b) physiological functionality. Properties vary widely depending on the type of fibre.

A. Technological functionality.

Water holding capacity (WHC): The most important property from a technological standpoint is the ability to bind water. Soluble fibres, such as pectin and gums, possess a gher WHC than cellulosic fibres. When in the form of powder, fibres that are fundamentally cellulosic, such as grain husks, bind several times their weight in water; this capacity is related to the length and thickness of the fibre particle (Blenford, 1992). Alga fibres, depending on type, can bind up to 20 times their own volume in dry matter. The pH of the medium generally influences water holding capacity.

Fat binding capacity: The capacity of a fibre to bind fat depends more on the porosity of the fibre than on molecular affinity (Nelson, 2001). For this reason, in order to prevent fat uptake, it is advisable to place the fibre in water first, so that the water fills the pores and prevents the entry of fat. This is useful as a means of avoiding excessive absorption of frying fat when fibres are used in batters.

Viscosity: Fibres, such as pectin, gums, β-glucans with mixed bonds and polysaccharides extracted from algae, form highly viscous solutions. Plant-derived gums are generally the substances most widely used as thickeners. The viscosity of insoluble and some soluble fibres, such as inulin, is minimal (Gallaher & Schneeman, 2003). For interesting reviews on fibres as thickeners, see Ward and Andon (1993) and Stephen (1995).

Gel-forming capacity: Gel is the name given to an association of polymeric units to form a network in which water and/or other solutes are included. Many soluble fibres form gels, for instance carrageenans (iota and kappa), pectins, konjac, etc. The capacity to form a gel and the characteristics of that gel will depend on a number of factors including concentration, temperature, presence of certain ions and pH. Nelson (2001) provides a summary of the various fibres and their gel-forming properties. Some of these ingredients possess synergic gel-forming capacity when administered in conjunction with starch, xanthan gum or carragenates (Pérez-Mateos, Hurtado, Montero & Fernández-Martín, 2001).

Chelating capacity: Many types of fibres possess the capacity for *in vitro* cationic exchange as a means of binding minerals (Gallaher & Schneeman, 2003); one of the possible consequences of this is that these ions can be prevented from operating in the activation of lipid oxidative reactions. It has been demonstrated that some fibres possess a capacity for ion exchange with copper (McBurney, Allen & Vansoest, 1986). Also, pectins are known to be able to combine *in vitro* with bivalent ions such as iron, calcium, copper and zinc (Nair, Nyman & Persson, 1987). Some fibres such as inulin and oligofructose constitute an exception as regards the capacity to bind minerals.

Fermentive capacity: Fibres are able to ferment to different extents depending on the type of fibre. Thus, whereas cellulose ferments little, pectins are entirely fermentable (Gallaher & Schneeman, 2003).

Texturizing: The use of fibres can assist the restructuring of products based on fish and meat muscle (Nelson, 2001). In most meat products and some fishery products the use of these fibres can help achieve the right texture in restructuring of previously ground muscle. One example of such use is a soy protein concentrate containing around 25% fibre which, appropriately texturized, can help simulate the muscle myotome when added to restructured products made from minced muscle. Certain fibres such as oat are used as fat replacers in some meat products.

Other properties are the modification of flavour and texture, the control of sugar crystallization, the modification of gel-forming properties and viscosity, and the stabilizing of frozen products. One important characteristic is the ability of fibres to prevent the deformation and shrinking of restructured products during cooking. Some fibres possess antioxidant capacity and act efficiently, in either chilled or frozen storage, in products that become rancid quickly.

B. Physiological functionality.

Reduction of cholesterolaemia: The soluble fraction of fibres has a hypocholesterolaemic effect. A number of mechanisms have been proposed: augmented gastrointestinal content interfering with micelle formation and lipid absorption, which can prolong the presence in plasma of lipoproteins rich in triglycerol of intestinal origin (Mekki et al., 1997). Another possible mechanism is an increase and excretion of neutral sterols and biliary acids. Also, increased excretion of biliary acids reduces cholesterol by augmenting the synthesis of these acids, thus increasing the conversion of cholesterol to this route (Story & Kritchevsky, 1976). Another possible explanation for the elimination of cholesterol is the production of propionic acid and other gases through colonic fermentation, which when absorbed slow down cholesterol formation (Nishina and Freedland, 1990).

Modification of the glucaemic response: The fibres that increase the viscosity of the food pellet reduce the post-prandial glucaemic and insulinaemic responses (Wolever & Jenkins, 1993). The most important mechanism seems to be retarded emptying of the gastric tract through increased release of cholecystokinine in response to a high intake of fibre (Bourdon et al., 1999). Another mechanism is the hindering of contact with the absorbent intestinal epithelium due to increased viscosity.

Changes in intestinal function: The fact that fibre can bind a large amount of water makes it highly useful from a physiological point of view, since it enlarges the volume of the aqueous phase of the food pellet and slows down the absorption of nutrients in the intestine (Gallaher & Schneeman, 1986). In the case of soluble fibre, its most important role is to increase the viscosity of the food pellet. This reduces the speed of transit and hence influences the rate of intestinal absorption. Dietary fibres modify the function of the intestine by shortening the time in transit, augmenting the faecal volume and the frequency of evacuation, diluting the contents and supplying substrates that will ferment in the bowel (Gallaher & Schneeman, 2003). The type of source and the amount of the fibre influence the intestinal function in different ways; in general, fibres that are resistant to colonic fermentation, such as wheat bran, most increase the content of the intestine. However, highly fermentable fibres generate a large mass of microorganisms and likewise increase the intestinal content.

Reduction of nutrient availability: The results of *in vitro* experiments have shown that some fibres can inhibit the activity of pancreatic enzymes that digest carbohydrates, lipids and proteins, although it is not known how (Harris & Ferguson, 1999). Fibres can interfere, although not much, with the absorption of some vitamins (Kasper, 1993) and the absorption of minerals such as calcium, iron, zinc and copper (Torre & Rodríguez, 1991; Hernández, Hernández & Martínez, 1995). According to Torre and Rodríguez (1991), the reduction of mineral absorption could be related to the presence of phytic acid or other chelants in the fibre.

The fibres that increase the viscosity of the intestinal contents retard the process of digestion and absorption irrespective of the absorption of nutrients, so that most of the absorption occurs in the final sections of the small intestine. This influences the feeling of satiety and consequently the intake of food (Gallaher & Schneeman, 2003).

There are various types of fibres that possess the ability to retain biliary acids and phospholipids and hence affect the absorption of these. The capacity to retard fatty acid absorption and interfere with cholesterol absorption favours the reduction of lipids in the bloodstream (Gallaher & Schneeman, 2003), and that could be useful in the treatment of obesity.

Health benefit effects: Epidemiological studies show a correlation between high-fibre diets and a lower incidence of some chronic disorders such as cardiovascular disease (Ludwig et al., 1999) and colon cancer (Honda, Kai & Ohi, 1999; Bobek, Galbavy & Mariassyova, 2000). This and the effects of fibre on glucose absorption indicate that generally speaking, consumption of fibre induces a lower risk of diseases. At all events, it must be borne in mind that the association between risk of disease and diet is multifactorial and that with the present state of knowledge, fibre cannot be isolated as the sole factor (Gallaher & Schneeman, 2003). As well as the beneficial health effects mentioned, certain fibres, such as beetroot and cellulose, have been found to have an antioxidant effect in rat blood (Bobek, Galbavy & Mariassyova, 2000). There is also evidence of negative effects of fibre for health. For instance, fibre can produce phytobenzoates, which may induce a slowing of digestion and protein absorption (Alesón, Fernández, Fernández, Sayas-Barberá & Pérez-Álvarez, 2002).

CHARACTERISTICS OF CHITOSANS

Chitosan is a fibre of animal origin. Its precursor is chitin, which occurs naturally, chiefly in the exoskeletons of crustaceans, molluscs and insects and in certain fungi where it is the principal fibrillar polymer of the cell wall. Chitin is a cationic polysaccharide formed by units of N-acetylglucosamine and glucosamine joined by beta bonds (1→4); the structure is similar to that of cellulose except that the C2 contains an amine group instead of the hydroxyl group (Fig.1). Chitosan is obtained by deacetylation of chitin, which is available in a wide variety of commercial products with different deacetylation grades and molecular weights/viscosities, and hence different functional properties (Cho, No & Meyers, 1998; No, Park, Lee & Meyers, 2000). This chitosan is not hydrolysed specifically by digestive enzymes; however, there can be some digestion by bacterial flora and by non-specific activity of some digestive enzymes such as amylases and lipases. Chitosan derivatives in the form of acetate, ascorbate, lactate, malate and others are water-soluble. Soluble chitosan can also be obtained in oligosaccharide form by enzymatic hydrolysis (Jeon, Shahidi & Kim, 2000).

Chitosan is known to possess numerous technological and physiological properties useful in foods, thanks to its functional properties (Koide, 1998; Shahidi, Arachchi & Jeon, 1999). Among these properties are many of the ones described in the foregoing section on vegetable fibres, and therefore we shall only look in detail at those most specific to chitosan. There are some studies on the use of chitosan in foods: in biscuits (Maezaki et al., 1993), in meat products (Jo, Lee, Lee & Byun, 2001; Lin & Chao, 2001) and fish muscle (Kataoka, Ishizaki & Tanaka, 1998; Benjakul, Visessanguan, Tanaka, Ishizaki, Suthidham & Sungpech, 2001; Benjakul, Visessanguan, Phatchrat & Tanaka, 2003; Jeon, Kamil & Shahidi, 2002; Kamil, Jeon & Shahidi, 2002) and derivative products such as fish patties and sausages (López-Caballero, Gómez-Guillén, Pérez-Mateos & Montero, 2005a,b).

To date chitosan would appear to be well tolerated clinically; however, its effect in prolonged diets needs to be monitored to see that it does not disturb the intestinal flora or interfere in the absorption of micronutrients, particularly liposoluble vitamins and minerals, or have any other negative effect (Koide, 1998).

A. Technological functionality

Antimicrobial capacity: Consumers demand ever more healthy and natural foods with no chemical preservatives. Chitosan prevents microbial activity, targeting the various different groups of microorganisms such as bacteria, fungi and yeasts (Sagoo, Board & Roller, 2002; Simpson, Gagne, Ashie & Noroozi, 1997). Its action mechanism appears to derive in part from ionic interaction between the cationic groups of the chitosan molecules and the anionic groups of the microbial cell membrane, which can rupture the cell membrane (Helander, Nurmiaho-Lassila, Ahvenainen, Rhoades & Roller, 2001). In addition, chitosan can act as a chelating agent for certain metals, and in this way it could also interfere in the formation of toxins and in microbial growth (Cuero, Osuji & Washington, 1991). According to species, microbial susceptibility depends on the type and the concentration of chitosan (Jumaa, Furkert & Müller, 2002; No, Park, Lee & Meyers, 2002).

Capacity to form protective films: Chitosans have the capacity to form semi-permeable coatings which when used on foods, prolong their shelf life by acting as barriers against air and moisture. They are currently used mainly to prevent browning of fruit and vegetables (Elghaouth, Ponnampalam, Castaigne & Arul, 1992). The effect produced on melanosis in crustaceans by addition of chitosan as a coadjuvant has been examined by Simpson, Gagne, Ashie & Noroozi (1997). This antimelanosic effect could perhaps be improved if the substance were used in the form of a protective film. Moreover, such chitosan coatings can contain compounds (antioxidants, antimicrobials, aromas, etc.) producing what is known as an "active" effect, whereby the compounds are released gradually while the product is in storage (Ouattara, Simard, Piette, Begin & Holley, 2000; Chen, Yeh & Chiang, 1996).

Other properties are emulsifying capacity (Rodríguez, Albertengo & Agullo, 2002); antioxidant capacity (Kamil, Jeon & Shahidi, 2002; Shahidi, Kamil, Jeon & Kim, 2002); as a texture modifier (Benjakul, Visessanguan, Tanaka, Ishizaki, Suthidham & Sungpech, 2001; Benjakul, Visessanguan, Phatchrat & Tanaka, 2003; Jo, Lee, Lee & Byun, 2001; Lin & Chao, 2001); as a polycationic coagulant for use in water purification, in fruit juices, in whey, in the immobilization of enzymes, etc.

B. Physiological functionality

Reduction of lipid absorption: chitosan behaves like a dietary fibre that is not hydrolysed in the gastrointestinal tract of the organism, as this lacks the specific chitonase enzyme. From a physiological standpoint, its prime function is to reduce intestinal lipid absorption, so that it has been acknowledged as possessing properties for reduction of cholesterol and favouring loss of body weight by reduction of lipid absorption (Gallaher et al., 2002; Maezaki et al., 1993; Colombo and Sciutto, 1996; Muzzarelli, 1999; Ylitalo, Lehtinen, Wuolijoki, Yliato & Lehtimaki, 2002). Chitosans have the effect of reducing cholesterol in the way of most other dietary fibres (nondigestibility in the upper gastrointestinal tract, high viscosity, high water binding ability in the lower gastrointestinal tract, etc); in addition, however, they have the ability to form ionic bonds at low pH and so can bind *in vitro* to different kinds of anions such as bile acids or free fatty acids (Shahidi et al., 1999). In the European market, chitosan is sold in the form of dietary capsules to assist weight loss, and in some countries like Japan it is added to foods such as noodles, potato crisps and biscuits.

Prebiotic capacity: The oligosaccharide chitosan presents activity as a stimulant of selective growth of lactobacilli and bifidobacteria (Lee, Park, Jung & Shin, 2002).

Fat binding capacity: Unlike fibres of vegetable origin, the amine groups of chitosan take one hydrogen ion in the acid fluids of the stomach, which causes the formation of a positively-charged tertiary amine group. In this way, negatively-charged molecules such as fats, fatty acids, other lipids and biliary acids, interact with the chitosan. Chitosan also interferes by trapping neutral lipids such as cholesterol and other sterols, by means of hydrophobic interactions. These electrostatic and hydrophobic bonds cause the formation of long polymeric compounds which are weakly attacked by digestive processes in the organism. This mixture passes into the intestine, where the fat/chitosan emulsion immediately changes to an insoluble gel owing to the pH of the medium, and thus fat droplets cannot be attacked by pancreatic or intestinal enzymes (Ylitalo, Lehtinen, Wuolijoki, Yliato & Lehtimaki, 2002; Kanauchi, Deuchi, Imasato, Shizukuishi & Kobayashi, 1995). It has been demonstrated that its effect can be enhanced by the presence of other compounds, for instance ascorbic acid (Kanauchi, Deuchi, Imasato, Shizukuishi & Kobayashi, 1995). The synergic effect appears to be due to three factors: reduction of viscosity in the stomach, augmented capacity to bind fat, and flexibility of the chitosan/fat gel.

Other properties are use in encapsulation of nutraceutical compounds and as a vehicle for pharmacological compounds or drugs, for example anticancer agents (Hojo et al., 2000).

WHAT ARE RESTRUCTURED FISHERY PRODUCTS?

Restructured fishery products are products made from minced and/or chopped muscle and which are used, with or without ingredients, to make other products with a new appearance and texture. For some time now there have been products in the form of fingers or other shapes intended basically for children's foods, which are covered in breadcrumbs or batter then frozen for use as fried products. Also, recent years have seen the development of a new generation of fishery products called analogues or substitutes, most of which mimic seafood or other high-value products. These have not only become popular in the Far East but have gained wide acceptance in North America and more recently in Europe. Such products are made essentially from "*surimi*", which is ground, thoroughly washed and refined fish muscle.

The reason for restructuring fish muscle is that the supply of high quality fishery products is limited and many are becoming exhausted because of severe overfishing. There are therefore not many options that do not entail the utilization of species that have not traditionally been commercialized either very much or at all. One of the chief advantages of restructured products is that the composition of the end product can be modified by reformulation of the original product once this has been chopped or ground. In this sense, the process might be said to be one of eliminating some constituents or adding other new ingredients or additives. These ingredients or additives may be categorized as a) favouring storage, b) functional from a technological standpoint and c) functional from a nutraceutical standpoint. There are several types of ingredients that perform more than one of these functions, among them dietary fibre. There are numerous references in the literature, and even many products on the market, for instance dairy, meat, bakery and other products, but there are scarcely any references to fishery products with added dietary fibre. Nonetheless, vegetable fibres have been widely used in ground meat products, especially as textural fat replacers. Most of the vegetable fibres used come from cereals, but lupin, rice, pea, bamboo and fruit fibres have also been used. Their essential uses in technological terms are to replace the oiliness produced by fats, to bind water, to reduce the yield weight after cooking and to maintain the shape of the product after cooking. Fibres from fruit could be very useful thanks to the balance between soluble and insoluble fractions and the antioxidant properties of some, for instance mango and grape (Saura & Larrauri, 1999). This antioxidant power would serve a twofold purpose: as a health factor for the consumer and as a means of preventing rancidity in the product with which it is mixed. For that reason, given the elevated oxidant capacity of fish fats, which are highly unsaturated, they could be very useful additives in fishery products. Incorporation could be either by injection in fillets or by mixing in restructured products.

Fish as such is a good example of a functional food in that it is an important source of nutraceutical products such as fish oil. It also contains a readily digested protein and hence is ideal for people who are prone to digestive problems. Nevertheless, such a good food would be more complete if it contained alimentary fibre. The fact of adding fibre to fishery products, which in principle do not contain it, may seem inappropriate when one follows a balanced diet containing fruit, vegetables and pulses as well as fish. And yet the fact is that large populations of children and adolescents in Western Europe consume products that contain essentially proteins or fats but consume hardly any foods that provide the necessary intake of fibre.

STUDIES ON THE ADDITION OF DIETARY FIBRE TO RESTRUCTURED FISHERY PRODUCTS

As noted earlier, there are hardly any references in the literature to the addition of fruit fibres to fishery products, and there are very few fishery products on the market that contain them, or at least that so state. Nevertheless, they would appear to be highly useful from both a technological and a nutritional standpoint, not to mention the use that could be made of them in marketing. The fibres most used for technological purposes to date are soluble fibres.

Addition of vegetable fibres

Many of the fibres used in fishery products are soluble and come from algae or seeds, selected for their functional properties, such as high water holding capacity, emulsifying capacity, thickening or gel-forming properties. As regards water holding capacity, Borderías, Montero & Martí de Castro (1996) made gels with added hydrocolloids to develop analogue products with good water holding capacity, especially where the raw material used is of poor functional quality. Daponte, Herfst, Roozen & Pilnik (1985) reported that kappa-carrageenan presented better water holding capacity than iota-carrageenan and prevented syneresis in fish gels during freezing/thawing. The modification of emulsifying capacity by the addition of certain fibres is important for the sausage and fish processing industries. Also, the addition of fibres to certain restructured fishery products can help to considerably improve viscosity, a step that is necessary in order to perform certain processes or achieve certain textures.

The additives used to enhance gelling of fish muscle have been essentially carragenates (Borderías, Montero & Martí de Castro, 1996; Gómez-Guillén, Solas, Borderías &

Montero, 1996), but there are authors who propose the use of gums, such as garrofin, guar, xanthan and others (Montero, Hurtado & Pérez-Mateos, 2000; Pérez-Mateos, Hurtado, Montero & Fernández-Martín, 2001). As well as these hydrocolloids, “konjac” meal is used in surimi-derived products and fish burgers; konjac induces thermostable gelling in a mildly alkaline medium, so that it not only binds water but confers elasticity on the products (Park, 1996). The effect on gel formation is due to its physical and/or physicochemical action, producing structural changes in the protein matrix which vary mainly according to its composition, distribution and interaction with that protein matrix. There are many articles on the interaction of these fibres with proteins in aqueous systems, but there are not so many that address the effect of the hydrocolloid/protein association in fish and cephalopod muscles (Borderías, Montero & Martí de Castro, 1996; Gómez-Guillén & Montero, 1996, 1997; Gómez-Guillén, Solas, Borderías & Montero, 1996; Gómez-Guillén, Borderías & Montero 1997; Montero, Hurtado & Pérez-Mateos, 2000; Pérez-Mateos, Hurtado, Montero & Fernández-Martín, 2001). In one of these studies, Gómez-Guillén, Solas, Borderías & Montero (1996), using electron microscopy, observed the formation of a carragenate network that was arranged parallel to the myofibrillar protein network of a gel made from cephalopod muscle, thus enhancing the general gel strength. In microscopy studies conducted on blue whiting (*Micromesistius poutassou*) muscle gels, Montero, Hurtado & Pérez-Mateos (2000) found that different types of fibres behaved differently. Thus, whereas thickeners (garrofin, guar and xanthan gum, carboxymethylcellulose) formed a filamentous mesh, gelling agents (carragenates, alginates) coated or lined the cavities with a continuous structure. In other studies Pérez-Mateos, Hurtado, Montero & Fernández-Martín (2001) observed interaction of kappa-carrageenan with the protein matrix of the blue whiting muscle gel. Another way in which fibres can act is to associate with non-muscle proteins so as to enhance the gelling of fish gels to which they are added; an example of this is the addition of iota-carrageenan and casein together in gels made from squid (*Dosidicus gigas*) muscle, where gel strength was found to be enhanced by the synergic effect of the protein/hydrocolloid association (Gómez-Guillén, Solas, Borderías & Montero, 1996; Gómez-Guillén, Borderías & Montero, 1997).

Addition of vegetable fibres with a high insoluble proportion

The authors of this article are currently conducting several studies at the Instituto del Frío (CSIC) involving fibre with a highly insoluble fraction from cereals or fruits. We are looking at two types of fibres of different origins which possess antioxidant capacity: wheat fibre and grape fibre.

In the case of wheat fibre we are experimenting on three types of restructured product: gels made from pollack surimi, white fish (hake) mince, and products made from fillet pieces. Up to 6 % of wheat fibre is added, with virtually no effect on appearance. The chief technological advantage of this fibre is its water holding capacity; this means that not only is it possible to add more water to restructured products, but the water is more efficiently bound, even after cooking. Also, the fibre alters the texture of restructured products; this is especially desirable in the case of surimi to reduce the rubbery feel of gelled products.

In the case of grape fibre we are looking for properties to complement the ones described above, for instance antioxidant power. In other words, fibre should inhibit the oxidation of fish fats, which are highly unsaturated, making it possible to prolong shelf life and obtain products with better flavour. In fact the experiments carried out so far tend to confirm our hypothesis.

We will also continue to investigate the action of other fibres such as those from some species of algae (Saura & Jiménez, 2002). The objective, in addition to harnessing all the functional and technological features described, is to add iodine, an element in which the population of Europe is deficient.

Addition of chitosans

It has been found that addition of chitosan can enhance rheological properties in surimi with poor gel forming capacity, depending on the type and concentration of the chitosan used and on the system to which it is added (Benjakul, Visessanguan, Tanaka, Ishizaki, Suthidham & Sungpech, 2001; Benjakul, Visessanguan, Phatchrat & Tanaka, 2003; Jo, Lee, Lee & Byun, 2001; Lin & Chao, 2001). Its influence on the gelling of restructured surimi or fish muscle products appears to be due to its effect on the enzymatic activity of endogenous transglutaminase (Benjakul, Visessanguan, Tanaka, Ishizaki, Suthidham & Sungpech, 2001; Kataoka, Ishizaki & Tanaka, 1998). However, no such effect has been found on transglutaminase of microbial origin (Benjakul, Visessanguan, Phatchrat & Tanaka, 2003). In this connection, Kataoka, Ishizaki & Tanaka (1998) stressed that the effect of chitosan was greater in treatments entailing prolonged setting, which favour the action of the enzyme.

Chitosan possesses antioxidant capacity in fish muscle depending on the concentration (50 - 200 ppm) and the type of chitosan (14 - 360 cP) and can reduce the TBARS oxidation index by around 50 % in herring and cod (Kamil, Jeon & Shahidi, 2002; Shahidi, Kamil, Jeon & Kim, 2002). It seems that its action mechanism could derive from the fact that it acts as a chelant on metal ions and/or that it combines with lipids (Xue, Yu, Hirata, Terao & Lin, 1998). The protective action of chitosan is also effective when it is applied as a protective film, where it retards lipid oxidation and microbial spoilage by acting as a barrier against oxygen (Jeon, Kamil & Shahidi, 2002;. Lin and Chao, 2001; López-Caballero, Gómez-Guillén, Pérez-Mateos & Montero, 2005a).

CONCLUSION

The addition of fibres to fishery products is of great interest not only as a means of improving the functionality of food products, but also as a means to creating functional foods with health benefits. From a technological point of view, the introduction of fibres improves water binding, thickening, emulsion capacity and gelling properties of products made with minced muscle, especially where the raw material used is of poor functional quality. In gels made from surimi, adding dietary fibres does not always improve gel characteristics, especially in high grade surimi. The antioxidant capacity of some dietary fibres is due to their chelant action on metal ions, which is particularly desirable in the case of products made from fatty fishes. From a physiological point of view, the addition of dietary fibre to a functional product like fish would further complement its healthy characteristics, adding beneficial effects such as reducing cholesterolaemia, modifying the glucaemic response, reducing nutrient availability, prebiotic capacity, etc.

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FIGURE

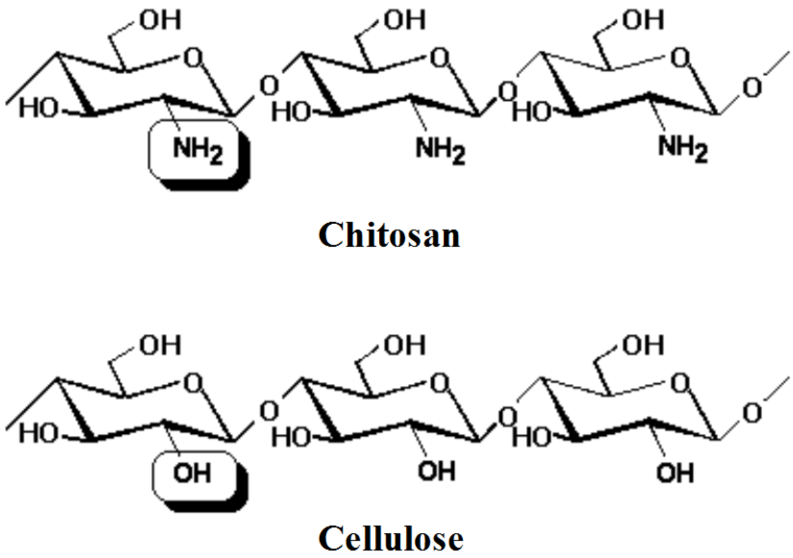

Figure 1.Structure of chitosan and cellulose