REVISTA MEXICANA DE INGENIERIA QUIMICA Vol. 5 (2006) 81-95 **AMIDIQ**

APPLICATIONS OF SOLUBLE DIETARY FIBERS IN BEVERAGES

APLICACIONES DE LA FIBRA DIETETICA SOLUBLE EN BEBIDAS

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Abstract

In this work the importance of soluble dietary fibers in the human diet is discussed. Traditional and new sources of soluble dietary fiber are mentioned, and a description of how to apply them in different types of beverages such as energy drinks, sport drinks, carbonated beverages and protein-based beverages in order to achieve enhanced functional properties is given.

Keywords: soluble dietary fiber, beverages, gums, inulin, fructooligosaccharides.

Resumen

En este trabajo se describe la importancia de la fibra dietética soluble en la dieta humana. Se enlistan una serie de fibras dietéticas solubles usadas tradicionalmente y otras obtenidas de nuevas fuentes. Se da una descripción de como aplicar estas fibras solubles en distintos tipos de bebidas como lo son energéticas, para deportistas, refrescos y con proteínas para maximizar las propiedades funcionales deseadas.

Palabras clave: fibra dietética soluble, bebidas, gomas, inulina, fruto oligosacáridos.

1. Introduction

Dietary fiber has demonstrated benefits for health maintenance and disease prevention. Consumption of foods rich in this dietary component is associated with reduction in total plasma and LDL-cholesterol, attenuating glycemic and insulin response, increasing stool bulk, and improving laxation (Schneeman, 1999). Moreover, through its specific beneficial physiological effects, dietary fiber consumption has established the basis for associating high-fiber diets in epidemiological studies with reduced risk of several chronic diseases, including large bowel cancer, cardio vascular disease, obesity, diabetes mellitus, colonic diverticulosis and constipation, among others (Viertanen, 1994; Ascherio, 1995; Kim, 1995). Diet high in fiber generally reflects a healthier life style. Despite the healthful influence dietary fiber can have on reducing risk of chronic disease, the intake remains low worldwide. Increasing fiber consumption in the diet has been a difficult challenge, as fiber sources usually used in foods have not, generally speaking, made high fiber foods with high quality taste and textural properties. It is important from a food product development standpoint that high fiber ingredients, not only made using high fiber, but also provide enhanced functional properties to make high-fiber foods taste better, thus encouraging continued high fiber intake (Tungland and Meyer, 2002).

1.1. Functional food trends

Functional foods are defined as any food or food component that may provide health benefits beyond basic nutrition. These foods offer health promoting ingredients or natural components that have been found to have potential benefits in the

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body. It can be a whole food or one that contains or has been fortified with ingredients that have a beneficial effect on the physical or mental health of the individual that consumes it. Fortified-food sales are projected to reach $ 23.4 billion USD this year. Beverages are one of the fastest growing nutraceutical markets. Energy drinks, bottled water, sports drinks and yogurt were among the top 15 fastest-growing categories in 2003, having total combined annual sales of $ 7,276 million USD, with high protein and low carbohydrate foods making up most of the other top 15 fastest-growing categories (Sloan, 2004).

Consumers are thinking and taking unprecedented action to improve their health, taking more hands-on responsibility for their own health, so that the beverage maintenance and the prevention market segments expected to remain strong. The accelerating self-care movement is generating an unpredicted demand for natural treatment and condition-specific supplements and foods, creating one of the most-lucrative health markets of all time, with beverages projected to remain the largest segment. Although the $ 62.9 billion carbonated soft drink market increased only 0.8 % in 2002, competition from non-carbonated beverages continues to intensify, with water expected to become the second most commercial popular commercial beverage in 2003, overtaking close contenders milk, coffee, beer, and juice/fruit beverages. Projected sales for non-carbonated drinks are expected to reach $11.83 billion dollars in the USA in 2005 (Sloan, 2003). Taste remains the top reason for always/usually choosing health foods and beverages, over specific medicinal purposes, improving daily performance, and fortification with extra vitamins/minerals and nutrients.

Six in ten consumers say they are likely/very likely to drink a non-alcoholic beverage to address a health concern. Overall health, bone strength, energy, cold/flu, and digestion are the strongest motivators. After thirst, an all natural claim is the most likely to ensure purchase of a "better-for-you" beverage. Eight out of ten no longer find artificial colors/flavors acceptable in healthy beverages, 75% artificial sweeteners, and 54% sugars; 53% of consumers would consider buying a fortified juice.

For the first time Americans are buying more bottled water than coffee or beer. The global bottled water market consumption increased from 23,189.5 million gallons in 1998 to a projected 38,023.3 million gallons in 2003, an increase of 10.4%. When it comes to health and nutrition, it is really a small world. Heart disease is now the world's leading cause of death, more prevalent than malnutrition and infection diseases. There are more people overweight worldwide than underweight. Cholesterol level -already afflicting 110 million in western Europe- high blood pressure, joint pain, and depression are on the raise. One in 20 in Europe (more than 150 million) suffers from diabetes. Stress, lack of energy, and sleeplessness, have become prevalent lifestyles conditions in most developed countries. It is not surprising that cultures having a strong natural-remedy awareness and focus, offer a broad range of innovative health–promoting and disease-reducing foods and beverages (Sloan, 2004).

1.2. Fortifying with fiber

The American Dietetic Association (ADA) recommends a daily intake for total fiber for adults 50 years and younger of 38 g for men and 25 g for women, while for men and women over 50 it is 30 and 21 g, respectively, due to decreased food consumption (Duxbury, 2004), but most Americans consume less than half of the recommended fiber daily intake (Schofield, 2004). Since one-fourth of the recommended total fiber intake should be soluble fiber, the average American is only consuming 3-4 g of soluble fiber.day^{-1}, below the recommended 5-10 g.

ber has been associated with preventing certain types of cancer such as bowel and breast. Dietary fiber in foods was inversely related to the incidence of large bowel cancer. Populations with a low average intake of dietary fiber, an approximate doubling of total dietary fiber intake from foods could reduce the risk of colorectal cancer by 40%. Most positive epidemiological and intervention studies have demonstrated the protective effects of total fiber intake 3-3.5 times higher than the mean dietary fiber intake of the U.S. adult population (11.1 $g.day^{-1}$) against colorectal cancer (American Gastroenterological Association 2000).

Although the American Council of Science and Health says it is uncertain whether dietary fiber has specific benefits in weight control, it is generally felt that people with diets rich in fiber are less likely to be obese. Some of the mechanisms through which dietary fiber may impact weight include reduced energy intake, flattening blood glucose response after carbohydrate ingestion and increased satiety, among others (Gallo-Torres and O´Donnell 2003). To obtain these benefits, it is clear that people need to consume more fiber (Milo Ohr 2004). Given the actual and projected growth rate of the nutraceutical beverages worldwide, the development of beverages containing soluble dietary fiber is an interesting option for achieving a higher dietary fiber intake by the average population.

1.3. Soluble dietary fiber

Gums and starches are now recognized as healthy sources of dietary fiber. Most gums are over 80% w/w soluble fibers (Hundley, 2002).

These gums are hydrocolloids of vegetable, microbial or synthetic origin. While gums pass through the body as fiber and are recognised as non-caloric, starches are nutritional energy sources. Gums have been named the silent partners in beverage formulation because neither will be tasted or smelled when formulated correctly, yet they can provide many useful functions, such as: stabilise milk proteins at low pH, stabilise emulsions in drinks, provide pleasant mouthfeel, good suspension and produce desirable levels of cloud in beverages (Saunders, 1994). Besides of these traditionally used gums, new hydrocolloid sources have been developed in recent years which have been used as soluble fiber in beverages. Foremost among these are the fructose polymers inulin and oligofructans (Gallo-Torres and O´Donnell 2003), and polydextrose (Brooks, 2003). Inulin and oligofructans are claimed as creating a positive environment for the growth of probiotic organisms that help balance the microflora in the gastro-intestinal tract, which in turn provides a variety of health benefits. As a food ingredient, inulin´s properties include slight sweetness and being a fat mimetic. Polydextrose is claimed to minimise off-notes contributed by high-intensity sweeteners, soy, vitamins, minerals and other nutritional supplements (Brooks, 2003). Everyday new soluble dietary fibers are found in the marketplace. Scientists are developing modified versions of the traditionally used gums and starches that have vastly increased functionality, or obtaining functional soluble dietary fibers from novel plant sources such as apple pomace and chicory. For example, larch arabinogalactan is a highly branched polysaccharide with a galactose to arabinose ratio of 6 to 1, soluble in water, but does not become viscous like many other soluble gum fibers (Papadimitriou, 2001), and resistant maltodextrin that is completely water soluble, is only partially digestible, and helps in the performance of various high-intensity sweeteners making them more sugar-like in sweetness, flavor and mouthfeel (Young, 2003). Whatever the source of the soluble fiber considered for the formulation of new beverage, one must consider the structure-functionality characteristics arising from the interaction of these ingredients with water and other food components. All functions of hydrocolloids require that they be hydrated. Failure to achieve proper hydration is the leading cause of problems in beverages containing these components. The properties of these ingredients when dispersed in water have a variety of functions in foods, including binding, coating, suspending, stabilising, gelling, emulsifying, and thickening (Igoe,1982). This functionality in aqueous systems is governed by the properties of the hydrocolloid. Rheological properties- such as viscosity changes and shear and yield value- and gel-forming and emulsifying capabilities are useful in determining the effectiveness of a hydrocolloid in a specific application. The solution properties depend upon the molecular weight and shape of the hydrocolloid. The solution properties of a hydrocolloid can be modified by interaction with other gums or beverage ingredients. These interactions modify the functionality of the hydrocolloid by altering its rheology, solubility, gelling characteristics, and reactivity, and in some cases increasing their functional usefulness, providing more flexibility of use to the user. However, mixtures of gums show such a complexity of non-additive properties that they must be interpreted by science rather than by art.

2. Formulating beverages with dietary soluble fiber

Beverage formulation is much more than adding a few drops of flavor and sweetness to water. Formulation of good-tasting beverages has become increasingly complex, as many interrelated factors must be taken into account. Concept definition, ingredient selection, intensive formula testing, processing and bottling are key to quality and stable shelf life, which lead to a steady stream of sales (Saunders, 1994). Beverage formulators are now faced with the increasingly difficult challenge of developing new or reformulating old products to suit the latest consumer trends. To accomplish this goal, the selection of appropriate and economical beverage stabilization systems becomes a crucial part of the formulation process. These systems largely depend on the type of beverage formulated, the ingredients used, the processing conditions used and the desired end product (Gerlat, 2000). In addition stabilisers and emulsifiers, beverage formulations often contain flavors, sweeteners, acidifiers, colors, vitamins and minerals, antioxidants, pre- and probiotics and botanicals in many different bases (Brandt, 2002). So a good starting point for the beverage designer is to consider several questions (Gerlat, 2000):

- What is the age of the product's target audience? Nutraceutical or meal replacement beverages, soft-drinks, New Age beverages, juices and fruity blends, sports/performance beverages, dairy drinks and flavored coffee and teas appeal to different niches and satisfy a wide variety of thirsts. Children will want a sweet, juicy product and will not be as sensitive to viscosity as adults. On the other hand, adults will be aware of the nutrient quality and ingredients. "Drinkability" is a concept definition component that is important as a predictor of product success in the marketplace. It is, however, an elusive quality that can change according to the targeted consumer, and is influenced by the stabiliser system being used in the beverage formulation.
- What are the nutritional expectations of the target audience? Many consumers expect fruit drinks to be high in vitamins. New Age beverages are assumed to be made from pure and natural ingredients. Sports beverages are expected to improve athletic performance, and this is done by replacing nutrients used in athletic endeavours. The desired outcome influences the formulation of the product, and care should be taken so that all beverages should work to achieve: (i) scientific-peer reviewed data to support product claims, (ii) vigilance to include changes when new facts or science is discovered (ongoing R&D, clinical trial), (iii) work with regulatory agencies (FDA,

USDA, EC, EPA) to ensure use of permitted ingredients, and fulfil minimum daily nutritional requirements.

- Is the beverage going to be "light", having reduced sugar and calories? Without sugar's bulk, viscosifying and mouthfeel effects must be supplied by the stabiliser system.
- What finished product characteristics, such as clarity or pH, will influence the type of stabiliser needed?
- What type of processing, packaging and distribution is the product expected to undergo?
- What is the target price of the product? Target price will have a significant influence on the amount and type of raw materials used in the formulation, as well as what stabilisers will be required.

Once all these questions are answered, formulation can begin. As the beverage concept is defined, an ingredient list will define itself.

2.1. Water

The first ingredient to consider is water. Water is the source from which almost all beverages spring, constituting 75 to 99% w/w of many beverages total volume. Water is the first and most quenching ingredient of a beverage, and constitutes an ideal medium to carry flavors, nutrients and particulates, both desirable and undesirable. Many municipal water supplies are increasingly compromised by unwanted chemicals, bacteria and other contaminants. The initial water quality can affect the beverage's sensory perception because of detection of metals and chemicals by the consumer, and shelf life because preservatives will not work effectively if the water in the formula contains yeasts or acid-tolerant bacteria. Thus, it is vital to employ purified water in a beverage formulation (Saunders, 1994).

2.2. Sweeteners

Sweeteners are the most common ingredients after water. Deciding on which sweetening system to use often is a factor of cost and labelling requirements. Sensory panellists describe sweetness profiles of beverages according to onset (how quickly sweetness is first sensed), build (time from sweetness onset to maximum sweetness intensity) and intensity (total sweetness). Each sweetener and sweetener blend has its own profile in different beverage bases and greatly impacts the overall flavor profile. Carbohydrate sweeteners such as sucrose, glucose, dextrose and fructose, especially high fructose corn syrup, provide in addition to sweetness other advantages. They provide calories for energy, viscosity for mouthfeel and inhibit some forms of microbial activity. At certain concentrations, however, they may contribute significantly to product cost. High intensity sweeteners include: aspartame, acetasulfame potassium (ace-K), sucralose, saccharin and neotame. Neotame has the highest sweetness potency between 7,000 to 13,000 times the sweetness of sugar, making it 30 to 60 times sweeter than aspartame. High intensity sweeteners offer advantages as well. For example, aspartame is a natural companion to juice based beverages because it can enhance fruit flavors and increases the perception of sweetness. Nevertheless, high intensity sweeteners present formulation challenges also. For example, the solubility of aspartame increases as the pH in a beverage is lowered, but its storage stability is reduced. Many beverage manufacturers are experimenting with blends of carbohydrate sweeteners and/or intense sweeteners in order to reduce costs, and because many of the sweeteners have synergies and when used together they round out each other's sweetness profiles (Saunders, 1994; Brandt, 2002).

2.3. Acids

Balancing sweetness and tartness greatly affects the overall flavor profile, so that the ratio of sugars to acids plays a major role in beverage formulation. Acids add tartness to beverages as well as help boost flavor character and overall flavor perception. Commonly added acids include citric, malic, tartaric and phosphoric. This sweetness-tartness balance is particularly important in the formulation of fruit juice based beverage formulations. Whereas fruit juice concentrates add their own sweetness, flavor and color to beverages, the sweetness-tartness balance is dependent on the sugar and acidity content, that on turn depend on fruit maturity. Fruit juice is considered a healthful ingredient in many beverage formulations. While New Age beverages 5-10% w/w juice, lemonades generally contain 10-15% w/w juice, and many health food beverages contain as much as 80% w/w juice, as well as other ingredients, such as herbs, vitamins or minerals. The sugar/acid ratio helps give the fruit its characteristic sweetness and tartness, and enhances the perception of fruit flavors.

In order to achieve a more authentic flavor, the acids added to the beverages usually are those naturally contained in the fruits. Thus, malic acid is a good choice for apple, cherry, banana, watermelon and peach-flavored drinks, whereas citric acid is the choice for strawberry and citric-flavored drinks, tartaric acid for grape-flavored drinks, and phosphoric acid for cola-flavored drinks. Formulators can achieve flavor nuances by blending organic acids typically found in fruit. Some fruit beverages do not contain any fruit juice and must be labelled "fruit-flavored" beverage. Also, organic acids though used in minor concentrations can act as preservatives, minimize cloying sweetness and help prevent haze formation (Gerlat,2000; Brandt, 2002).Carbonated soft drinks most often use benzoic or sorbic acid as preservative, in conjunction with sodium, potassium or calcium salts. The amount of preservatives used can vary, according to pasteurisation and processing (Saunders, 1994).

2.4. Flavors

Flavors are another important constituent of beverages. Flavor trends are fickle. Some flavors experience a steady demand for years, only to take back seat to new sophisticated flavors. In the last years a trend toward sophisticated combinations of fruit flavors has existed, their demand limited only by the creativity of the blender, and practical dictates of the product designer. Juices and juice blends contain natural fruit juices, whether pure or concentrated, whose flavor may be boosted with natural extracts and flavors. Artificial flavors are not used to the same degree as they once were, due to the better quality, stability and selection in natural flavors, and to consumers´ preference for "naturalness". Flavors are perhaps the ingredients more susceptible to last-minute changes in the formulation and launching of a new beverage product. Though quite stable before mixing, flavors can be affected by many other ingredients after blending into the beverage, as well as by storage and handling. Certain flavors, especially citrus flavors, also can affect the potency of vitamin formulas added to fortify the beverage (Saunders, 1994).

Many natural flavors are based on extracted oils from fruit, such as citrus oils, or other oil extracts. For these flavor oils to stay dispersed in the beverage, a weighing agent must be added. Weighing agents are lipophilic compounds with a specific gravity greater than 1.0 that are used to equilibrate the specific gravities of beverage components. Water and water-soluble ingredients have specific gravities of about 1.03, while the flavor oil is usually around 0.87. To prevent ringing-the collared ring at the top of the beverage caused by the separation of the oil from the beverage- brominated vegetable oil (BVO) has been used to weight the oil. Studies have determined that BVO´s were possible mutagens and consequently they were disallowed in many countries. In the United States it can be used up to 15 mg kg^{-1} (15 ppm) in finished products. In most cases, this level is not sufficient to prevent ringing. Glyceryl esters of wood rosin, also known as ester gums, are used in certain countries, but have a distinct rosin-like taste, have low oxidative stability and a slow dissolution rate into flavoring oils. Sucrose acetate isobutyrate (SAIB) is used extensively in many countries, and its maximum allowed use level in the United States is 300 mg kg^{-1} in finished products. SAIB is stable to homogenisation and to room-temperature storage and makes a very effective weighing agent. It is safe, does not contribute any off-flavors or odours and is priced competitively with other weighing agents (Gerlat, 2000).

Flavor protein-based beverages, either soy- or dairy-based, have been found to "disappear" or become altered in some way. Some proteins and carbohydrates are known to bind flavors. The effect of flavor binding on perceived flavor intensity depends on the flavor molecule and type, amount and composition of the protein, as well as the presence of lipids and polysaccharides. Most protein-based beverages include either dairy- or soy-proteins in their formulations and various components of these matrices interact differently with flavor molecules. For example, phospholipids content in proteins can interact with flavors and alter their perception. Both soy protein concentrates (65% w/w protein minimum), and soy protein isolates (90% w/w protein minimum), can possess undesirable raw/green, beany or cereal like notes as well as an astringent mouthfeel. Rancidity caused by lipid oxidation of soybean creates off notes, and the resulting lipoxygeriases are difficult to remove and combine with proteins. Chocolate is able to mask soy-protein flavor and provide a smooth flavor profile in beverages. Protein denaturation resulting from chemical or heat treatments alters the binding sites for flavor molecules. Protein-based beverages that are processed at high temperatures tend to bind more flavor, and little is understood regarding milk proteins-flavor interactions, with the exception of β-lactoglobulin-flavor interactions (Brandt, 2002).

Sport nutrition, and meal replacement beverages also frequently contain proteins. Prior to selecting the protein source, the food designer needs to determine the requirements of the finished product. As the protein level requirement in the beverage increases, selecting a lower viscosity protein becomes more important. A major challenge in designing these beverages is keeping the protein in solution over time. Various proteins inherently have different hydration capacities, viscosity and other functionalities, these characteristics can be altered to some extent by altering the manufacturing process of the proteins (Pryzbyula-Wilkes, 1992). The pH of such beverages is critical because acidic conditions can denature the protein, and most milk proteins and vegetable proteins precipitate out at low pH. Low-pH protein fortified beverages exist in the marketplace thanks to ongoing research that has produced whey proteins that are stable below pH 4, and have less of the chalky mouthfeel of other protein sources. The advantage to such low pH protein-fortified beverages is the potential for a quenching mouthfeel and flavor, plus the protein punch, and a low viscosity. Many old brands of protein-fortified sports beverages failed to quench thirst because they were extremely thick and viscous. Low viscosity promotes the healthful appeal and drinkability of the products. Beverage viscosity in protein-containing beverages can be adjusted with gums (Saunders 1994).

Energy drinks may contain the branched-chain amino acids leucine, isoleucine and valine that help regulate serotonin production in the brain and allow extended athletic performance. Soy and whey proteins both are potential sources of branched-chain amino acids. Each contains 18 to 26 g of branched-chain amino acids per 100 g protein (Hegenbart, 2003).

2.5. Vitamins and minerals

The major consideration in formulating beverages with added vitamins and minerals, other than which ones are required, is their stability and solubility. Vitamins differ in stability, and a liquid system may be subjected to heat processes that affect heat-sensitive vitamins. Shelf-life studies are necessary to determine what percent of various vitamins needs to be added to achieve the amount declared on the label at the end of the product's potential shelf-life, which in liquid beverages can require 100% overage (Pryzbyula-Wilkes, 1992). Vitamins such as C, A and B, begin to break down almost immediately upon being exposed to sugar, oxygen and various levels of pH. This liability of vitamins calls for extensive trial and error experiments that allow establishing the required dose overages that the formula will need to counteract the interactions.

When adding B vitamins, it is important to be aware they can dramatically affect product flavor over time. Vitamin and mineral fortification can be a cost-efficient option when the beverage processing plant uses a custom made pre-mix. Such custom-blends make it relatively simple to incorporate vitamin fortification into the processing system (Saunders, 1994). Dosage levels of vitamins need careful monitoring in some cases. Large doses of water soluble vitamins are probably quite safe, but, for example, doses above 50 mg day^{-1} of vitamin B6 can impair sensory nerve function. The fat-soluble vitamins A, D, E and K are more toxic in excess, and very high intakes should be warned against. In practical terms, using vitamins in beverages requires careful handling so that the end product is not affected. Heat used to pasteurise or sterilise should be applied as minimally as possible, reducing exposure time (Anon, 1997).

Although sports and energy drinks are similar, they possess key formulation differences. Energy drinks often contain caffeine- undesirable stimulant for sports drinks because it increases the heart rate and puts an increased pressure on that organ. In energy drinks the direct connection to hydration and athletic performance is less of an issue. Consequently they may contain caffeine, botanicals and a variety of the antioxidant vitamins C, A and E. One popular botanical is guarana because it contains caffeine. Ginseng- prized for its revitalising properties- also is commonly used in energy drinks (Hegenbart, 2003).

Fortification with minerals can result in solubility problems. Some calcium salts are insoluble and, in some cases, calcium can affect protein solubility. Settling out of minerals in clear- packaged water would be most unappetising. Chromium, selenium and zinc are used in small amounts and hardly would have much impact. Iron and calcium are used in larger quantities and can pose a problem. So it's striking the right combination and the right levels so that you don't have sedimentation, discoloration or flavor issues. Bioavailability of minerals is another important consideration. A nutrient's bioavailability indicates how well the body absorbs and utilises it. For example organic calcium salts, such as calcium citrate, calcium lactate, calcium lactate gluconate and calcium gluconate, generally provide more bioavailability and more solubility than inorganic calcium sources. And although the inorganic sources contain higher levels of calcium than the organic salts- calcium carbonate contains 40% w/w calcium compared to tricalcium citrate (21% w/w), calcium lactate (13% w/w), calcium lactate gluconate (10-13% w/w) and calcium gluconate (9% w/w)- the lack of solubility limits their use in beverage applications. On the other hand, mineral lactates exhibit high solubility; are well absorbed by the body; possess high levels of mineral content; exhibit neutral flavor profile; and dissolve clearly without color impact, thus making them suitable for use in clear beverages. All calcium sources affect flavor to some extent, although, as mentioned earlier, mineral lactates possess a neutral flavor profile, thus making off-notes that may develop easier to rectify. Some possible solutions for correcting off-notes include: manipulating the acidulants (replacing citric acid by lactic acid), add natural flavors, and/or increase pH (Hazen, 2003).

In isotonic and sports drinks, salts are important ingredients because they help replace the electrolytes (sodium and potassium) that the body loses through sweat. Typically these are added in the form of sodium chloride and sodium or potassium salts of citric or phosphoric acid. Also, when a body receives a certain amount of water, it may think it has enough fluid volume to replace what was lost through sweat and turn off the thirst mechanism. In actuality, it may not be hydrated. These salts encourage beverage consumption and, therefore accelerate rehydration. Added salts also make water more available to the tissues. The saltiness can have a synergistic effect on fruit flavors. This could result in a lower level of flavoring in an isotonic beverage than would be required in, say, a flavored bottled water to obtain the same flavor intensity. Sodium concentration of a sports drink should contain between 10-30 mmol.L^{-1} (Pryzbyula-Wilkes, 1992; Hegenbart, 2003).

2.6. Colors

Colors play an important role in some beverages. Most carbonated drinks use compound flavors that include color components to simplify processing on the fine. Natural color extracts are being given a boost by the continuing demand for natural foods. However, certain synthetic colors are still widely used, due to their ease of solubility and stability even after UV exposure and oxygenation. Designers also must remember that formulating with colors requires more than visual observation. Carotenoids, for example, are a class of natural pigments that are responsible for the yellow/orange/red colors of many fruits and flowers. Up to 18 carotenoids have been detected and quantified in human plasma, including β-carotene, lutein, zeaxanthin and lycopene. Such carotenoids are being investigated as promising candidates for cancer, heart disease and aging effects prevention (Giovannucci, 1999; Knekt et al., 1999; Nishino et al., 1999; Delgado-Vargas and Paredes-López, 2003). Carotenoids, therefore, combine coloring and nutritional functions in a unique manner. They are functional in two senses of the word: they perform a technical function and are thought to have positive health benefits (Anon, 1997). Lutein is gaining interest among beverage manufacturers, as it is deposited in the macula of the eye and in the skin of the human body. It functions as an antioxidant and blue-light filter and may reduce the damage to the eyes and skin (Barnes, 2004). However carotenoids are highly prone to deteriorative degradation, mainly by oxidation, and must be protected to be functional (Delgado-Vargas and Paredes-López, 2003).

2.7. Hydrocolloid stabilisers as source of dietary soluble fiber

Stabiliser systems based on hydrocolloids and gums have different functions in beverages, among them to: stabilise the beverage; provide soluble dietary fiber; and provide specific finished product attributes, i.e., a thick or thin, creamy or light characteristic, through their interactions with other components in the beverage. A fine line exists between over- and under- stabilising beverages. On one hand, the system could become to viscous or gelled if over stabilised, but settling or precipitation of the protein, or other solids, could occur if the beverage is under stabilised. Gums generally reduce flavor impact and should be added to the system before final flavoring is complete. There are many possible products to choose from.

At low pH levels, alginates gel or precipitate; therefore they cannot be added as stabilisers to products such as fruit juices. In these foods, polypropylene glycol alginate (PGA) may be used. In this type of alginate the carboxylic acid groups have been esterified, in part, by reacting with propylene oxide, to prevent gelation and precipitation. Fruit drinks containing pulp suspended to provide a "natural appearance" are acidic and have a shelf-life of 12 months, during which the pulp must remain suspended and the flavor oil must not form a "ring" at the top of the bottle. Medium-esterified PGA (0.1 % w/w) with relatively high calcium content provides a crosslinked network which at high dilution gives relatively high viscosities at low shear, so the tendency of flavor oil and fruit pulp to move are prevented due to the high viscosity (Profeiro et al., 1992; Clare, 1993). Alginates are compatible with a wide variety of materials including other thickeners, sugar, oils, fats, pigments and preservatives. Blends of PGA and xanthan gum have been used successfully in fruit-juice beverages that require particle suspension, calcium fortification and viscosity control (Clare, 1993).

High-methoxyl (HM) pectins make good viscosity control agents for fruit beverages. They have the advantage of being considered a natural part of many juices. HM pectins have over 50% DE. This refers to the percentage of acid groups present in the pectin molecule as the methyl ester. In a product with less than 55% solids, this pectin acts as a thickener, rather than forming a gel. A dilute pectin solution mimics the viscosity of a 15% w/w sugar solution (Gerlat, 2000). Xanthan gum improves the mouthfeel of citrus and fruit-flavor beverages. In beverages that include flavor emulsions, the addition of xanthan at concentrations up to 0.5% w/w can help stabilisation and mouthfeel (Nussinovitch, 1997). Microcrystalline cellulose, or cellulose gel, and sodium carboxymethylcellulose (CMC), are used in beverages as suspending aids, thickeners and stabilisers. These stabilisers are generally considered as natural and can provide a source of fiber. Also, they are stable at a pH of 3, allowing them to remain functional in most acidic fruit beverages during storage (Gerlat, 2000).

Addition of 0.4 to 0.5% w/w of CMC or xanthan gum to a non-centrifuged cloudy apple juice showed stable turbidity for extended periods of storage. It was also detected that, at low shear rate, cloudy juices with xanthan gum exhibited higher viscosity than the same juice with CMC, due to lower molecular weight of the latter (Genovese and Lozano, 2001). Enzyme action and mechanical processing hydrolyse fruit pulp, exposing positively charged protein. The exterior of the pulp, on the other hand, contains pectin with free carboxyl groups giving it a negative charge. The result is ionic attraction leading to self-flocculation and loss of stability. However, the free carboxyl groups of the polysaccharides give them a negative charge that causes them to associate with the exposed protein to provide stabilisation because of charge repulsion between the protein-polysaccharide complex and the pulp (Clare, 1993).

The "healthy-lifestyle" beverages cover a wide range of products from teas to sports drinks to exotic combinations of herbs and vitamins. For these products to be accepted by the consumer, must be perceived as natural, good tasting and "refreshing", and have an appropriate mouthfeel. Also like any other beverage, they must be processed and packaged to withstand the rigors of a distribution system. Xanthan gum is widely used in this type of beverages, because of its extreme shear-thinning behavior and its high flavor releasing property. Xanthan gum forms "weak gels" that at the comparatively high shear rates that operate in the mouth ($50\ s^{-1}$) exhibit low viscosity. Flavor release from thickened systems depends of the ease of mixing in the mouth (Morris, 1993). Another popular stabiliser added to teas and other healthy beverages is HM pectin. Not only does this ingredient add viscosity and stability to the beverage, it also provides a good source of fiber. Guar gum, which is all natural, odourless, tasteless, and contributes approximately 80% w/w fiber is an option for ready-to-drink beverages. It provides medium viscosity without excessive gumminess, enhances mouthfeel and helps to evenly suspend particulates, such as fine ground herbs or insoluble nutrients.

Gum arabic is considered as the best of all soluble fibers as a direct additive to liquid foods. It is high in fiber, lowest in viscosity, odourless, tasteless, stable in acid solutions, and safe. Even at 10% w/w level, gum arabic does not thicken more than 0.002 Pa.s. If a milkshake can tolerate this small viscosity increase, then 18 g of fiber could be added to every 236.6 mL (8 oz) serving. Also is possible to add 3 g of fiber to drinks such as iced tea, strawberry drink and orange drink without a perceptible taste change (Andon, 1987; Wareing, 1999). Gum arabic is widely used for emulsifying flavor oils in beverage emulsions. In carbonated soft drinks (CSD) citrus flavors are among the most popular of all flavors, and worldwide, orange flavor is the favourite of consumers. These citrus flavored products are based mainly on the essential oils from peel of the fruits. Since they are not water soluble, incorporation of these flavors can be done by converting the oil into an oil-in-water emulsion (Tan and Wu Holmes, 1998). A typical citrus oil emulsion for beverage will contain 6-8% w/w flavor oil, 3-8% w/w weighting agent, 15-20% w/w gum arabic, and traces of artificial or natural colorants, with the balance made up with water. The beverage concentrate is completed by adding sugar syrups and citric or other acids. This concentrate is diluted about 5 times with carbonated water to give a drink with the required rheology, good flavor, mouthfeel, good appearance and stability. Gum arabic is useful for providing a stable cloud in the drink and boosting the cloud from added fruit pulps and juices (Wareing, 1999). Mesquite gum (Prosopis gum) is a promising source of dietary fiber, as it is chemically similar to gum arabic (Vernon-Carter et al., 2000). As gum arabic, it contains a small content of protein that provides its molecule with surface active properties, so that it forms strong viscoelastic films at the oil-water interface (Pérez-Orozco et al., 2004). It has higher molecular weight and is more readily soluble in water than gum arabic (Orozco-Villafuerte et al., 2003). The stability of orange peel oil-in-water emulsions containing mesquite gum are as stable as those obtained from gum arabic, but mesquite gum provides better protection against emulsified and encapsulated carotenoids than gum arabic (Vernon-Carter et al., 1996, 1998; Rodríguez-Huezo et al., 2004). This fact is important because there is a new tendency to formulating beverages containing carotenoids (Barnes, 2004). Gum arabic and gum tragacanth 1:4 have been used to reduce the viscosity without reducing emulsion stability, resulting in a thin, pourable consistency. Gum arabic can also be used to give smoother flow properties in xanthan gum systems (Wareing, 1999).

Ready-to-drink dairy- and soy-based beverages such as flavored milks rely on stabilisers to for suspending chocolate particles, improve viscosity and enhance mouthfeel. Also, stabilisers are employed as processing aids during high temperature short time (HTST) or ultra high temperature (UHT) processing.

Carrageenans are often used in neutral pH beverages. They interact naturally with milk proteins. A light gelled structure is developed which cannot be detected and form permanent suspensions with particulates. They also give these beverages good body to control “glugs” while pouring, without causing gummy or slimy coatings that linger in the mouth. In cultured dairy beverages carrageenan is used to control syneresis and to enhance mouthfeel (Berry, 2002). Carrageenan beverage stabilisers are frequently comprised of portions of the three different gum fractions- kappa, iota and lambda- to give the characteristics required by the drink formulator. These are very sensitive to changes in the protein content and make-up of the beverage.

Tromp et al. (2004) informed that in order to stabilise an acidified milk drink of 8.5% w/w non fat milk solids HM pectin has to be added at concentrations around 0.3% w/w. It was found that up to 90% w/w of this pectin added to acidified milk drink is not directly interacting with the casein micelles. This non-adsorbing fraction of pectin, which is, however, necessary to produce a stable acidified milk drink it is not needed to maintain stability. The amount of ineffective pectin in the acidified milk drink can be reduced increasing the energy input during the homogenisation step, i.e. after the addition of pectin. The adsorbed pectin forms a barrier to interaction between casein particles and protects them from flocculation, principally by steric repulsion (Parker et al., 1993).

Canned gellan gum milk, consumed as textured milk beverage after shaking, are available from vending machines in Japan (Gibson and Sanderson, 1999). Locust bean gum (LBG) has been used in the formulation of milkshakes at concentrations less than 0.1% w/w to thicken and impart a creamier mouthfeel to the product (Nussinovitch, 1997). Xanthan gum also suspends solid particles very well due to its high viscosity at rest, and xanthan solutions are stable over a wide range of pH (Nussinovitch, 1997). Milk-soluble sodium alginates (0.8% w/w of milk drink) are dried-mixed with sugar, cocoa, etc. and dissolved in cold milk to form smooth, firm gel (Pomeranz, 1991).

Low pH dairy-and-fruit beverages present additional challenges because the beverage pH is below the isoelectric point of proteins that tend to settle out. Casein, for example, has an isoelectric point at approximately pH 4.6. Both the correct stabiliser and the point of addition need to be carefully considered early in the formulation process. Often, whey proteins, which are less sensitive to low pH, can be used as replacement, or partial replacement of casein. HM pectins or starches can be used in these systems. Pectin can stabilise acidic juice and milk or soy beverages by complexing with protein. The negatively charged pectin surrounds the positively charged protein and prevents it from clumping (Przybyla-Wilkes, 1992; Gerlat, 2000). Pectin in addition to providing stabilisation through the formation of a gel, prevents syneresis and enhances creaminess (Berry, 2002). Locust bean gum is used in milk-fortified fruit juice drinks where the proportion of milk is low, to delay sedimentation of the casein micelles and ensure the acceptance of the product (Nussinovitch, 1997).

Guar gum cannot be used to thicken acidified milk drinks, in which the milk proteins approach or pass through their isoelectric point during the manufacturing process, due to protein phase separation at high dosages of this gum. Guar gum is more liable to cause phase separation than LBG owing its higher intrinsic viscosity (Fox, 1999). Modified tapioca starches that enhance mouthfeel and texture of liquid foods and beverages, including solutions too low in viscosity for starch granules to remain suspended have been developed. This type of starch is molecularly dispersed, has excellent freeze/thaw stability, non-sliminess, and is cost effective (Gerlat, 2000).

In transparent beverages, polydextrose is a magnificent choice of dietary fiber. It is low-glycemic and can be used in sugar-free beverages suitable for diabetics. Polydextrose provides over 90% w/w soluble dietary fiber and contains only 1 calorie per g compared to 4 calories per g for typical carbohydrates. It is tasteless, and has low impact on viscosity and flavor so that it can be used in concentrations as high as 5 g of fiber per 236.6 mL. Sometimes it helps to mask off-flavors that you might get from vitamins or minerals. It's extremely stable for most processing and temperature conditions. Improved gastro-intestinal function has been demonstrated with a daily intake of 4-12 g polydextrose without adverse effects. Polydextrose is metabolised independently of inulin, has a glycemic index of about 5 compared to 65 for glucose (Brooks, 2003; Hazen, 2003).

Inulin and fructooligosaccharides (FOS) are naturally occurring carbohydrates, considered as a fiber in many countries, but not by the FDA. Still, inulin and FOS act as soluble fiber, and both substances contribute fewer calories than sugar or starch, so that they can be used in the formulation of low carbohydrate beverages. They provide consumers with a number of health benefits, including increase calcium absorption, relief of constipation, reduction of total triglycerides, and an improvement of high density lipoprotein (HDL)/low density lipoproteins (LDL) ratio and prebiotic effects. A daily intake of 3 to 5 g of inulin or FOS can create a significant increase in beneficial colonic bacteria (Anon, 1997; Hazen, 2003).

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