MODIFICATION OF THE TEXTURAL CHARACTERISTICS, OIL ABSORPTION, AND PROTEIN CONTENT OF FRIED COWPEA PASTE (AKARA) DURING PRODUCTION

by

MINERVA ADINORKIE PLAHAR

(Under the direction of Yen-Con Hung)

ABSTRACT

To improve the textural quality of akara (fried cowpea paste), two saponins, Yucca and Quillaja, were incorporated into cowpea paste. Addition of the saponins increased the foaming capacity of the paste and resulted in a desirably soft, spongy-textured product compared to the control as well as increased oil absorption. Addition of soy flour and curdlan to the cowpea flour resulted in a decrease in the fat content of akara. The paste moisture content of akara containing both soy flour (20%) and curdlan (1%) was modified to obtain product characteristics comparable to the control (100% cowpea flour). Increasing the moisture content of the paste resulted in an increase in its foaming capacity, and optimum results were obtained for paste with 63% moisture content. Firmness of the product was similar to the control and the fat content was lower (17%) compared to the control (26%).

INDEX WORDS: Saponins, Quillaja, Yucca, Soy flour, Curdlan, Foaming capacity, Fat content, Protein content, Nutritional quality, Akara, Cowpea, Soybeans

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DEDICATION

This thesis is dedicated to God, who gave me the strength and wisdom to complete this work. Also to my parents, Dr. W. A. Plahar and Agnes Parker-Longdon and my brother Hector Plahar, for their love, support and encouragement.

“For I know the plans I have for you,” declares the Lord, ‘plans to prosper you and not to harm you, plans to give you a future and a hope.” (NIV)

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CHAPTER 1

INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp) is a food legume with superior nutritional attributes. It is a rich source of low-cost protein, compared to animal proteins. Paste prepared from cowpea forms the basis of many popular African dishes, but in the United States consumption of this legume is very low due to lack of technologies that will convert the legume to attractive, convenient foods. Due to the labor-intensive process required for processing cowpeas into paste-based foods, a USAID-funded project involving the University of Georgia and the University of Nigeria has led to the development of dry cowpea meal that is convenient and only requires the addition of water to make a paste.

Akara is a popular African finger food, prepared from cowpea paste. The paste is whipped and the resulting paste mixed with bell or hot peppers, onions and salt, and deep-fat fried. The resulting product has a soft, spongy crumb texture and crisp outer layer. Akara is similar to hush puppies, a fried cornmeal product, indigenous to the southern part of the United States. However, akara represents a nutritious alternative because it has 22% protein (dry-weight basis) compared to 10% for cornmeal hush puppies. Extensive research has been conducted at the University of Georgia to determine optimal hydration, mixing and frying conditions of akara, and there is ongoing research to modify this product to suit the specific needs of the American public as well as to enhance the overall quality of the product.

The main objective of this study was to enhance the physical characteristics and protein content of akara, as well as to reduce its overall fat content. The first part of the study was aimed at modifying the texture of akara by increasing the foaming ability of cowpea paste. This was achieved by the use of saponins (Quillaja and Yucca), which have been approved for human consumption by FDA and are already being used in various food products to improve their foaming properties. The effect of the addition of the saponins to cowpea paste on paste characteristics, as well as on the proximate composition, specifically the fat content, of akara was also determined.

In the second part of the study, soybean flour and curdlan were used to reduce the oil absorption and hence the fat content of akara. Curdlan is a water-insoluble polysaccharide (β-1, 3 glucan), produced by *Alcaligenes faecalis* var. *myxogenes*, and has a specific character to make an irreversible gel by heating of a water suspension. Due to increasing obesity in the United States, the fat content of foods is very important and consumers' preference for low-fat or fat-free foods has led the snack food industry to manufacture products with lower oil content while still maintaining desirable flavor and texture. As a result this study also determined the effect of these modifiers on the texture and nutritional quality of akara.

CHAPTER 2

LITERATURE REVIEW

Cowpea

Cowpea (*Vigna unguiculata*) is an annual legume, commonly referred to as southern pea, black-eyed pea, crowder pea, lubia, niebe, coupe, frijole or chinapeas (Davis *et al*., 1991; Patterson, 2002). They are composed of a cotyledon, germ and seed coat with a testa and hilum. The seed coat is where the colored pigment is contained and it can be removed by decortication to reveal a white seed (cotyledon) (Patterson, 2002).

Cowpea production

The history of cowpea dates to ancient West African cereal farming, 5-6 thousand years ago, where it was closely associated with the cultivation of sorghum and pearl millet (Davis *et al*., 1991). Cowpea is a key staple for the poorest sector of many developing countries of the Torrid Zone. In 1981 production was estimated at 2.27 million tones from 7.7 million hectares, with Africa producing two-thirds (Rachie, 1985). In 2001 total worldwide production was estimated at 3.3 million tons of the dry grain with Africa producing 64% (FAO, 2001). West Africa is the region with the largest production and consumption of cowpea. Conservative estimates suggest that greater than 12.5 million ha are planted annually to cowpea around the world and of this area, about 9.8 million ha are planted in West Africa. The primary cowpea-producing countries in West Africa are Nigeria, Niger, Mali, Senegal, Burkina Faso and Ghana (Cisse and Hall, 2004).

Cowpea was introduced into the New World in the latter part of the seventeenth century, and the crop has been cultivated in the southern parts of the United States since the early eighteenth century (Fery, 1985). Georgia, Arkansas and Tennessee are the leading producers of peas for processing; and California and Texas are the leading producers of dry beans. It is estimated that 80,000 ha of cowpeas are grown in the United States each year (*Vigna* crop germplasm committee, 1996). The United States is the only developed country producing large amounts of cowpea where they are grown primarily for dry seed in California and West Texas. There is a wide range in the characteristics of cowpea varieties grown for food uses in the U.S. Cowpea cultivars that are popular in the U.S. can be classified into four major groups, namely, black-eyed, crowder, purple hull and cream types. The black-eyed type is the most popular and widely used in the U.S. (Prinyawiwatkul *et al.*, 1996).

Cowpeas are generally consumed as a boiled vegetable, as roasted seeds, used for snacks, as ingredients in soups, salads, stews, porridges, breads and casseroles and as steamed or fried pastes (Uzogara and Ofuya, 1992). In the United States, they are also utilized for fodder and a quick-growing cover crop under a wide range of conditions. They are able to fix nitrogen efficiently up to 240 KgN/ha and provide a high proportion of their own nitrogen requirements, besides leaving a fixed nitrogen deposit in the soil of up to 60-70 Kg/ha for the succeeding crop (Rachie, 1985).

In the United States legume consumption is extremely low (5 g/day) but legumes provide half or more of the dietary protein in developing countries (Phillips, 1997). About 10-150 g/day of legumes is consumed in India and Sub-Saharan Africa and 50-89 g/day in Latin America (Bressani, 1985). The difference in consumption between developing and developed countries is because of a lack of modern food technologies for converting legumes to attractive, convenient foods. Beans are generally boiled over fire and eaten as-is. The western food processors need to develop technologies to convert legume seeds to tasty, nutritious foods which will be accepted by the developed countries (Phillips, 1997).

Nutritional Quality

Cowpea's superior nutritional attributes, versatility, adaptability and productivity led to it being chosen by the U.S. National Aeronautical and Space Administration as one of few crops worthy of study for cultivation in space stations (Ehlers and Hall, 1997). Cowpea is a rich source of protein. Generally cowpea contains 11% moisture, 24% protein, 1.3% fat, 56.8% carbohydrate, 3.9% fiber, 3.6% ash and provides 343 Kcal/100g (Deshpande and Damodaran, 1990). The protein in the seed is rich in amino acids, lysine and tryptophan compared to cereal grains (Davis *et al.*, 1991). Lysine is an essential amino acid important for growth, tissue repair of the body and maintenance of the body's nitrogen balance. Tryptophan is also an essential amino acid, which is necessary for the production of the B vitamin, niacin, which in turn helps the body to produce seratonin, a chemical that acts as a calming agent in the brain and plays a role in sleep. However, cowpea is limiting in the sulfur-containing compounds, methionine and cysteine, when compared with animal proteins. Therefore, cowpea seed is valued as a nutritional supplement to cereals and an extender of animal proteins (Davis *et al.*, 1991). The major storage proteins are globulins (70%) and glutelins. These proteins are considered the 'power houses' of legumes because they provide most of the essential amino acids to the diet (Phillips, 1997; Phillips, 1993). Table 2.1 and 2.2 show the proximate composition and amino acid content of cowpeas, respectively.

Total carbohydrate varies from 56-68% with starch contributing 32-48%. The amount of amylase present influences starch solubility, lipid binding and many functional properties, such as swelling and solubility, water absorption, gelatinization and pasting, that affect cooking practices and acceptability (Bressani, 1985). Sucrose is the most abundant sugar, followed by stachyose, verbascose and raffinose. Cowpeas contain large amounts of crude fiber, of which cellulose is a major component (Prinyawiwatkul *et al*., 1996). Cowpeas have higher levels of folic acid and lower levels of anti-nutritional and flatulence-producing factors compared to common beans (Ehlers and Hall, 1997).

Cowpeas are an excellent source of thiamin and niacin and also contain reasonable amounts of other water-soluble vitamins, riboflavin, pyridoxine and folacin. In addition they supply the essential minerals, calcium, magnesium, potassium, iron, zinc and phosphorus (Aykroyd *et al*.,1982). This is important since in most developing countries milk is hardly an

Table 2.1. Proximate composition of cowpeas

Constituents	Content (per 100g fresh weight)	
	Raw	Cooked
Water (g)	11.95	70.04
Food energy (kcal)	336.00	116.00
Protein (g)	23.52	7.73
Total lipids (g)	1.26	0.53
Total carbohydrate (g)	60.03	20.77
Crude fiber (g)	4.58	2.31
Ash (g)	3.24	0.94

Source: USDA (1986)

Table 2.2. Amino acid content of cowpea

Amino Acid	Content (g/100g fresh weight)	
	Raw	Cooked
Tryptophan (g)	0.29	0.10
Threonine (g)	0.90	0.29
Isoleucine (g)	0.96	0.31
Leucine (g)	1.80	0.59
Lysine (g)	1.59	0.52
Methionine (g)	0.34	0.11
Cysteine (g)	0.26	0.06
Phenylalanine (g)	1.37	0.45
Tyrosine (g)	0.76	0.25
Valine (g)	1.12	0.37
Arginine (g)	1.63	0.54
Histidine (g)	0.73	0.24
Alanine (g)	1.07	0.35
Aspartic acid (g)	2.84	0.93
Glutamic acid (g)	4.45	1.46
Glycine (g)	0.97	0.32
Proline (g)	1.06	0.35
Serine (g)	1.18	0.39

Source: USDA (1986)

important part of the diet; the need for calcium can be met by consuming cowpeas and other vegetable foods.

Limitations of the use of cowpea

Despite their values as good sources of protein, energy and other nutrients and their relatively low cost with respect to other high protein foods, cowpeas are not regularly selected as food for various reasons. These include pest infestation, beany flavor and odor, anti-nutritional factors (tannins, phytates, protease inhibitors, flatulence factors), hard-shell defect, hard-to-cook defect and hardness due to water quality (Uzogara and Ofuya, 1992).

The hard-to-cook (HTC) defect of cowpeas refers to failure of bean cotyledons to soften sufficiently during normal cooking (Liu *et al*., 1992). This occurs when the seeds are stored at high temperature and high humidity and causes a decrease in nutritional quality (Tuan and Phillips, 1991). The most widely accepted model for development of HTC has been that during storage, Ca++ is released from calcium phytates complexes and migrates to the cell middle lamella where it binds to the carboxyl groups of pectin, insolubilizing it, forming a barrier to water penetration and cell separation during cooking (Mattson, 1946; Jones and Boulter, 1983).

Pests such as insects, rodents, lizards and molds, are the main cause of damage to stored cowpeas, and cowpea weevils (*Callosobruchus maculatus* and *C. chinensis*) are the major insects that infest cowpeas (Uzogara and Ofuya, 1992). In just 3 months the weevil can destroy 50% of the stored cowpea seeds and in West Africa alone, cowpea weevil losses are estimated to exceed $50 million annually (Bean/Cowpea CRSP, 2002). Major pests attacking cowpea plants are flower thrips (*Megalurothrips sjostedti*), pod borer (*Maruca vitrata*) and pod sucking bugs. Fungal diseases affecting cowpea include stem and root rots and leaf spot diseases. Viruses cause mosaic diseases and mottle symptoms in cowpea. The parasitic weed, *Striga gesneroides*, can severely damage cowpea plants. Losses due to pest attack or disease can be as high as 90% (IITA, 2004a). There is ongoing research in developing disease- and pest-resistant cowpea varieties. The International Institute of Tropical Agriculture

(IITA, 2004a) has developed varieties with resistance to major diseases, insect pests, nematodes and parasitic weeds.

The characteristic beany flavor of cowpeas results from the action of lipoxygenase enzymes on free fatty acids in the seeds. This leads to formation of ketones, aldehydes, and other compounds, giving undesirable flavors (Kon *et al*., 1970). Lipoxygenase is an enzyme that catalyzes the formation of odorous carbonyl compounds from components containing the cis, cis-1,4-pentadiene (Okaka and Potter, 1979).

Cowpea carbohydrates are rich in total sugars including flatus-causing oligosaccharides, raffinose, stachyose and verbascose (Phillips and Abbey, 1989). These oligosaccharides are not utilized by humans and monogastric animals, who lack the specific *α*-galactosidase enzyme needed to digest them (Phillips *et al*., 2003) and pass to the lower gut where a variety of microorganisms of the colon hydrolyze and ferment them with production of gas/flatus as well as free fatty acids. These flatulence factors alter water retention and fecal bulk. Flatulence is uncomfortable and can be accompanied with frequent belching, abdominal distention, diarrhea and weakness (Ndubuaku *et al*., 1989).

Akara

Paste prepared from cowpea forms the basic ingredient in the preparation of many popular African dishes, such as *moinmoin* and *akara* (Dovlo *et al*., 1976), prepared by steaming or deep-fat frying, respectively. The most common cowpea–based product in Africa is akara (Reber *et al*., 1983).

Akara is a fried cowpea paste product, prepared by whipping cowpea meal with water, mixing with bell pepper, onion and salt, and deep fat frying (Misra *et al.*, 1996). This cowpea product is indigenous to Ghana, Nigeria and other West African and South American countries. Akara is similar to a fried cornmeal product (hush puppies) indigenous to the southern part of the United States of America. It has a spongy interior and a crisp outer layer. Akara represents a nutritious alternative to hush puppies because according to McWatters *et al*. (1993), the protein content of akara (dry-weight basis) is 22% compared to 10% for cornmeal hush puppies and 8% for French fried potatoes.

Acceptability of akara by the U.S. consumer

Although akara is largely unknown in the U.S., its acceptance could encourage greater use of cowpeas in forms other than as a boiled vegetable (McWatters *et al*., 1997). A study done by McWatters *et al.*, 1990, was to access consumer preference for the appearance and flavor of akara as an indicator of its potential for U.S. markets. Akara was most acceptable to Caucasians, older consumers and those with no, little or some high school education. It was concluded that the product should be positioned in the marketplace as a snack food to be used with a sauce or dip.

A two-year study was done by Misra *et al.* (1996), at the 1990 and 1991 Global Food Web conferences, to determine the acceptability of akara by American teenagers. Participants of the conference numbering 267 between the ages of 11-19 years were used in this study. Using a rating scale of 1 (dislike extremely) to 9 (like extremely), the overall liking for akara was rated to be 5 or higher by 64% of the respondents, with a mean rating of 5.3. This indicates potential for consumer acceptance. However, only 47% of the respondents indicated that they would be either very likely or possibly likely to consume akara at a fast food establishment. Thus in introducing this product to the American market, other possibilities such as serving akara as a snack or in restaurants or to a niche market could be explored.

Another study was done by McWatters *et al*. (1997) to determine the response of Georgia teenagers to this traditional West African food, their likelihood and willingness to purchase and consume it as well as to identify potential marketing approaches. Based on their findings, akara has potential for success in the fried food market. The product was most acceptable to males, blacks, and those who had completed nine or more grades in school.

Akara paste preparation

Although cowpeas are favored and readily consumed in West Africa, a major constraint to their wider use is the labor-intensive and time-consuming task of preparing them for consumption (McWatters, 1983). The paste is prepared by first soaking the dry seeds in water to loosen the seed coat. These are then decorticated by either manual rubbing or stirring the wetted peas in a mortar and floating off the seed coats in water. The resulting seeds are ground to paste either on a stone, in a mortar, or in an electric blender (Dovlo *et al*., 1976).

When using black-eyed cowpeas or peas with dark seed coats, consumers prefer them dehulled to ensure a light-colored paste and attractive end products. Dehulling is, however, not necessary if cowpea cultivars with white seed coat and little pigmentation in the hilum area (eye) can be used (McWatters, 1983). Research with different cowpea cultivars has shown that cream peas which have white seed coats and little pigmentation produce paste with acceptable processing performance and sensory quality, without the need to dehull the peas (McWatters and Brantley, 1982; McWatters and Flora, 1980, Patterson, 2002; McWatters, 1983).

Successful use of cowpea meal or flour largely depends upon its compatibility as a food ingredient and quality of end-products (McWatters, 1985). A ready-to-use flour was once commercially produced in Nigeria, Ghana and other parts of Africa, to simplify the paste-making process, in that it could be quickly hydrated into paste. Although this simplified akara preparation by eliminating the need for dehulling and grinding, there were problems with its use. A major complaint was the poor water absorption of the flour resulting in akara balls that were heavy, lacked crispness and lacked the cowpea flavor normally associated with akara made from fresh paste (Dovlo *et al*., 1976). The particle size distribution of the flour was found to significantly affect the performance of the flour in making good-quality akara (McWatters *et al*., 1990), in that the particle size of finely milled flour was too small to function in the same manner as traditionally-processed paste made from imbibed seeds (McWatters, 1983). Akara prepared directly from seeds (traditional method) is known to have a soft, spongy, bread-like texture with a thin and crisp crust and a much-desired, fresh cowpea flavor (Dovlo *et al*., 1976). Preliminary studies showed that akara prepared from meal (or flour) was heavier and less spongy, formed a thicker crust, and lacked the typical flavor associated with akara prepared from seeds by the traditional soaking, decortication, and wet-milling steps. The batter moisture content of hydrated meal appropriate for akara production was significantly lower than that of fresh paste prepared from seeds. The method of milling appears to affect the functionality of pastes used in akara production. While the seeds are soaked for a prolonged duration during processing of fresh paste, meal (and flour) is hydrated and immediately whipped. Insufficient hydration time and lack of foaming property may be factors contributing to poor meal functionality (Kethireddipalli *et al*., 2002).

Research done by Kethireddipalli *et al*. (2002) showed that paste prepared from flour had low water holding capacity. Akara prepared from flour was denser and less spongy than traditionally-prepared akara (made from seeds). The high water holding capacity of traditionally-prepared paste resulted in a greater reduction in specific gravity of the paste after whipping, hence a higher foaming capacity of the paste which resulted in less dense akara.

Based on these findings, research efforts have led to the gradual development of a dry-milling technology for the production of a ready-to-use cowpea meal. The meal has an intermediate particle size between fine flour and coarse grits (Williams, 1980). The University of Georgia and the University of Nigeria were for several years involved in a USAID-funded project to develop a village-mill process for production of a convenient-to-use cowpea meal to which the consumer would only need to add water to make a paste. This collaborative project resulted in a technology that has produced cowpea meal with excellent functional and nutritional quality (McWatters *et al*., 1988; Phillips and McWatters, 1991). Currently, peas are dry milled using a 2.54mm screen size to obtain cowpea meal acceptable for making good-quality akara. Water is added to the resulting flour and allowed to sit for about 15 minutes to ensure proper hydration of the cowpea proteins. This is then whipped to produce a foamy paste; appropriate amounts of salt (1.5%), chopped onions (9.5%) and bell peppers (9.5%) are incorporated into the paste and deep-fat fried (3 min).

Further research was conducted by Singh *et al*. (2004) on the effect of particle size distribution of cowpea flours on the quality of akara; they found that an extra processing step involving blending of the cowpea paste was necessary to produce akara with sensory characteristics similar to the desirable traditionally-made akara. Akara produced from dry-milled peas lacks the desirable spongy texture of traditionally-prepared akara due to the poor hydration property of the flour and poor foaming property of the paste. Matching of particle-size distribution and further blending of cowpea paste made from dry-milled seeds were used as tools for producing akara comparable in quality to the traditional West African wet-milled product. Blending the paste resulted in a reduction in viscosity, and akara (21.1% fat content) made from peas milled using a hammer mill equipped with a 2.54-mm screen was acceptable to consumers.

Functionality

Functionality has been described as any property of a food or food ingredient except nutritional ones which affect utilization (Pour-El, 1981). Proteins are usually linked to such functional properties as solubility, water absorption and binding, viscosity, gelation, cohesion-adhesion, elasticity, emulsification, fat absorption, flavor binding, foaming and color control (Kinsella, 1979). The functional properties of cowpea flour are critical to the production of associated foods. These properties include water absorption, fat absorption, and protein solubility, which affect the processing, texture and appearance of the product (Kerr *et al*., 2000). Cowpea paste with good functionality dispenses easily into hot oil and forms akara balls that float during frying and develop a uniform shape (McWatters *et al*., 2001).

Functionality of cowpea batter for akara-making is related to the minor proteins (albumins). In a study done by Kethireddipalli *et al*. (2002), on the effect of milling method (wet and dry) on the functional properties of cowpea (*Vigna unguiculata*) pastes and end product (akara) quality, traditional cowpea paste had superior foaming properties due to the combined effect of high protein solubility and high paste viscosity.

Aeration

Aeration is one of the fastest growing food processing operations. It can be defined as a process in which air or carbon dioxide or any other gaseous mixture is included within a food system, to produce a gas phase and a condensed phase (solid or liquid). The purpose of aeration could either be to enhance shelf-life (as in the case of carbonation); or to improve product functionality and enhanced consumer appreciation due to novelty value; or obtain a good size to volume relationship; or a combination of these. From the manufacturer's perspective, there is the direct profit boost because of reduced food matter in the product, and also the production of novel textures with potential market advantage (Niranjan, 1999).

Many ingredients achieve their functionality through their effects at bubble interfaces. The positive benefits of aerated food products are primarily to do with texture (Campbell & Mougeot, 2000). One of the most important and perhaps the least understood application of bubble mechanics is in the area of texture and sensory analysis. The textural appearance and mouth feel of 'bubbly' products is a direct consequence of the complex interactions between mechanics and our senses (Niranjan, 1999).

Aeration of food products produces foams which are defined by Niranjan (1999) as gas bubbles separated by thin films. These foams consist of bubbles of various sizes. Large bubbles are mainly formed due to rapid coalescence of bubbles released at the sparger; coalescence continues to take place as the bubbles rise through the liquid, forming progressively larger bubbles having sizes comparable with the column diameter. The small bubbles are formed during coalescence of the larger bubbles as well as when large bubbles break through the liquid surface at the top of the column. When gas flow is stopped, the large bubbles disengage very rapidly, and the dispersion consisting of the small bubbles can remain stable over extended periods of time. Foams, like all bubbly dispersions, are inherently unstable. Destabilization of foams can be caused by coalescence of bubbles, disproportionation and liquid drainage. Life-times of foams can vary dramatically depending upon the ingredients used, and these can range from a few seconds up to a few days (Niranjan, 1999).

The foaming capacity of cowpea paste is very crucial in developing a product with the textural characteristics associated with akara (Kethireddipalli, 1999). Foam consists of an aqueous continuous phase and a gaseous (air) dispersed phase. The unique textural properties and mouth feel of foam-type products stem from the dispersed tiny air bubbles (Damodaran, 1994). The foaming ability of cowpea paste is affected by particle size, hydration time, protein content and protein solubility. The high protein content (24%) of cowpea contributes to its foaming capacity (Bressani, 1985). The capacity of cowpea proteins to absorb water, to form a foamy structure when whipped, and to produce paste with an appropriate viscosity are important functional characteristics that affect the behavior of cowpea paste in akara production (Phillips and McWatters, 1991).

The functionality of cowpea flour when hydrated into paste results from a unique interaction of the flour components and water. In the case of akara preparation, cowpea paste is whipped to form foam which should be stable during mixing with other ingredients and during frying (Enwere *et al*., 1998). Whipping incorporates air into the paste thus making it swell and giving it good dispensing and frying qualities (Mbofung *et al*., 2002). Frying of the whipped paste forms a sponge, similar to that in fried doughnut. The spongy texture is highly desirable and constitutes a strong factor in determining the acceptability of akara balls among consumers (Enwere *et al*., 1998). Modification of the foaming capacity of the paste will modify the texture of the end product. Increased foaming capacity will result in an increased gaseous dispersed phase leading to increased air spaces in the product, hence a product with ‘lighter’ texture. According to McWatters *et al*. (1988), the production of akara balls with uniform shape, color, and texture depends upon the functionality (hydration, foam and flow characteristics) of minor cowpea proteins. The functional properties of proteins (in legumes) may be altered by physical, chemical or biological means (Pour-El, 1981).

Texture

Food texture is defined by Szczesniak (1990) as the sensory and functional manifestation of the structure, mechanical, and surface properties of food and the manner in which this structure reacts to applied forces. The specific senses involved are vision, kinesthesia, and hearing (kinesthesia is the sensation of presence, position or movement, resulting chiefly from stimulation of sensory nerve endings in muscles, tendons and joints). Texture and mouth feel are major determinants of consumer acceptance and preference for foods and beverages. Food preference and acceptance, in turn, have a great impact on the nutritional status of consumers and on the profits of food manufacturers (Guinard and Mazzucchelli, 1996).

According to Szczesniak (2002), texture is a sensory property, thus only a human being or an animal (in the case of animal food) can perceive and describe it. Texture-testing instruments can detect and quantify only certain physical parameters which must then be interpreted in terms of sensory perception. Texture is also a multi-parameter attribute, comprised of a gamut of characteristics. It derives from the structure of food and is detected by several senses, the most important ones being the senses of touch and pressure.

An important texture characteristic of akara is hardness or firmness. According to Pevron *et al*. (1994), during the mastication process, the first bite and its force are the keys to the assessment of hardness or firmness of the food, which in turn, depends on the magnitude of the applied force and the extent to which the food is deformed during the first bite. The physical definition of hardness is the force necessary to attain a given deformation; the sensory definition is the force required to compress a substance between molar teeth (in the case of solids) or between tongue and palate (in the case of semi-solids) (Szczesniak, 2002). Other texture characteristics important for determining the textural quality of akara are cohesiveness, springiness, and chewiness.

Cohesiveness and springiness are primary textural properties while chewiness is a secondary property. Cohesiveness is defined as the extent to which a material can be deformed before it ruptures (physical definition) or the degree to which a substance is compressed between the teeth before it breaks (sensory definition), while springiness is defined as the rate at which a deformed material goes back to its undeformed condition after the deforming force is removed (physical definition) or the degree to which a product returns to its original shape once it has been compressed between the teeth (sensory definition). Chewiness is the energy required to masticate a solid food to a state ready for swallowing; it is a product of the hardness, cohesiveness, and springiness (physical definition) or the length of time (in sec) required to masticate the sample, at a constant rate of force application, to reduce it to a consistency suitable for swallowing (sensory definition) (Szczesniak, 2002).

A very important factor in the acceptability of Akara is its texture. According to Enwere *et al*. (1998), the spongy texture of Akara is highly desirable and constitutes a strong factor in determining the acceptability of akara balls among Nigerian consumers. In a study done by McWatters (1983), akara made from Nigerian cowpea flour was less desirable than that made traditionally because the akara made from the flour was described as ‘dry, dense, and having a tough outer surface’. Traditionally-prepared akara was described by Kethireddipalli *et al*. (2002) as ‘spongy and tender’.

Saponins

Saponins are glycosidic compounds composed of a steroid (C–27) or triterpenoid (C-30) saponin nucleus with one or more carbohydrate branches. They are mainly of the triterpenoidal type. They are a group of structurally-diverse molecules that consist of glycosylated steroids, steroidal alkaloids and triterpenoids (Haralampidis *et al*., 2002). Saponins are divided into two groups: steroidal saponins (which occur as glycosides in certain pasture plants such as

Brachiaria decumbens and *Panicum spp*) and triterpenoid saponins (which occur in soybean and alfalfa).

They occur in numerous plant species and are frequently bitter and sometimes toxic. A few commonly eaten plants contain significant levels of saponins, which are non-toxic at levels normally eaten. Most of the commonly eaten plants containing saponins are legumes- particularly garden peas, green beans, navy beans, soybeans and chick peas. Others include asparagus, sesame, garlic, spinach, oats and some varieties of eggplant (Oakenful, 1997). Saponins are bitter, however if they have a triterpenoid aglycone, they may instead have a licorice taste as glucuronic acid replaces sugar in triterpenoid (Anonymous, 2004).

The name saponin is derived from 'sapo', the Latin word for soap, since these molecules have surfactant properties and give stable soap-like foams in aqueous solution (Haralampidis *et al*., 2002). The foaming capacity of saponins is due to their water-soluble and fat-soluble molecular moieties (Dinan *et al*., 2001).

Saponins have been associated with a diverse range of properties, some of which include both beneficial and detrimental effects on human health, piscidical, insecticidal and molluscicidal activity, allelopathic action, antinutritional effects, sweetness and bitterness, and as phytoprotectants that defend plants against attack by microbes and herbivores (Haralampidis *et al*., 2002). They are a group of phytochemicals (biologically active micro-nutrients) having strong surfactant properties. Saponins are claimed to have hypocholesterolemic, immunostimulatory and anticarcinogenic properties. The proposed mechanisms of anticarcinogenic properties of saponins include antioxidant effect, direct and select cytotoxicity of cancer cells, immune-modulation, acid and neutral sterol metabolism and regulation of cell proliferation (Rao, 1996).

Production of Yucca and Quillaja extracts

The two major commercial sources of saponins are *Quillaja saponaria* and *Yucca schidigera* (Cheeke, 1999). The Quillaja extract is obtained from the *Quillaja saponaria* Molina tree, which is native to Chile; Yucca extract is obtained from the Mohave Yucca plant (*Yucca schidigera*) which grows in the arid Mexican desert (Desert King International, 2004; Cheeke, 1999).

The Yucca plants are harvested by Mexican farmers and transported to processing plants. The trunks of the plant (yucca logs) are mechanically macerated and either dried and ground to produce 100% yucca powder, or the macerated material is subjected to mechanical squeezing in a press, to produce yucca juice. The juice is concentrated by evaporation, with the concentrated product referred to as yucca extract (Cheeke, 1999).

Traditionally, the bark of the *Quillaja saponaria* tree is used as the source of the Quillaja extract. The wood is sometimes used in modern extraction techniques. The wood and bark are boiled in large tanks, the water extract is drawn off, and the extract is concentrated by evaporation to produce the Quillaja extract (Cheeke, 1999).

Chemical and physical properties of Yucca and Quillaja extracts

Quillaja saponins are anionic surfactants, resistant to salt, heat, and extremely stable to acid pH. Chemically they consist of a triterpene, with sugar chains in carbons 3 and 28 (Fig 2.1). Different sugar chains give rise to at least 50 different types of Quillaja saponins. Molecular weight is of 1800-2000 Dalton. The height of the foam produced by the Quillaja saponin (liquid) is about 160-180 ml and the foam consists mainly of large bubbles (Desert King International, 2004).

Yucca saponin consists of a steroidal sapogenin nucleus. The side chain on the Yucca saponin is attached to the hydroxyl group as shown in Figure 2.2. The height of the foam produced by the Yucca saponin (liquid) is 120 ml and the foam consists mainly of small bubbles (Desert King International, 2004).

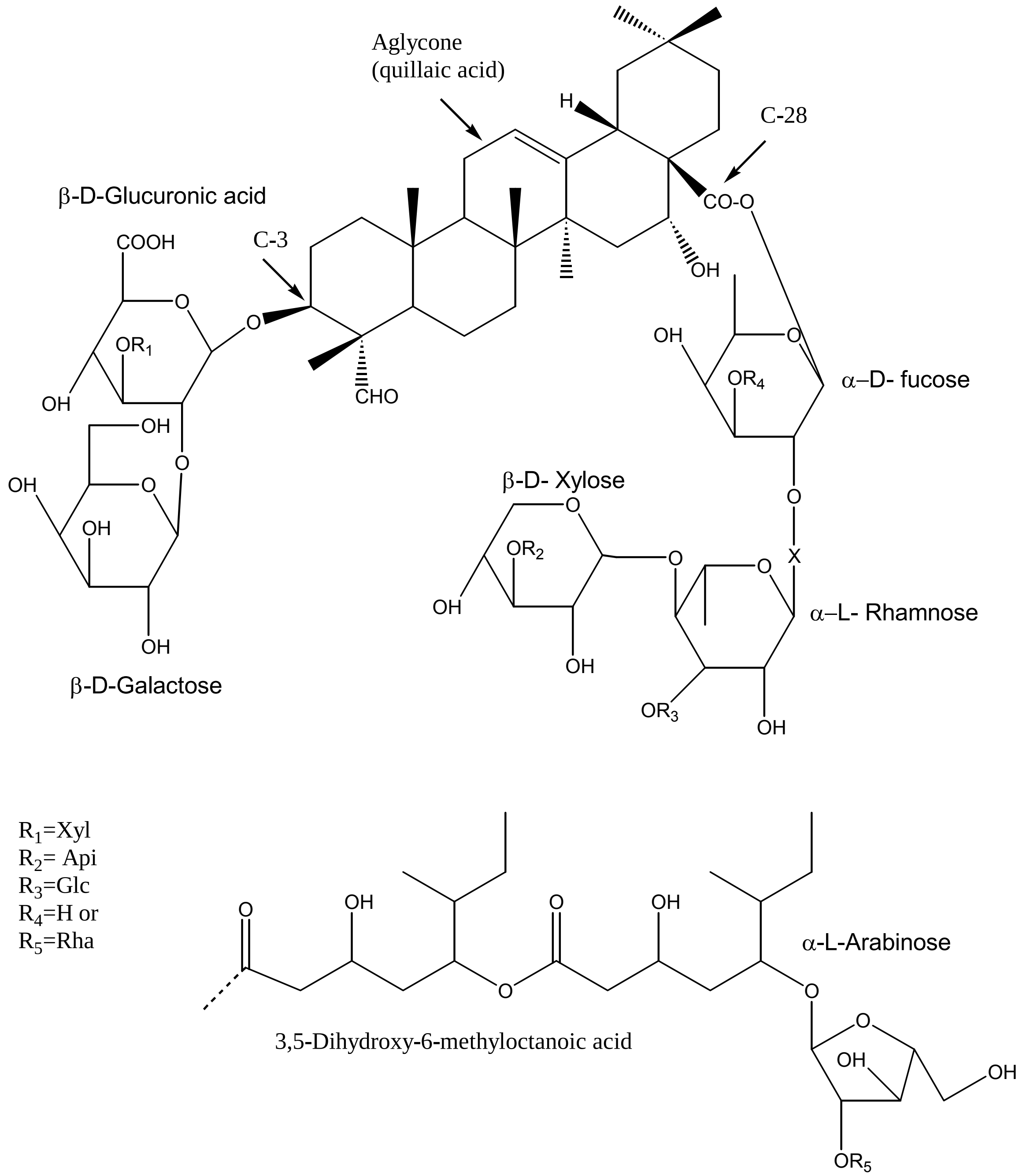
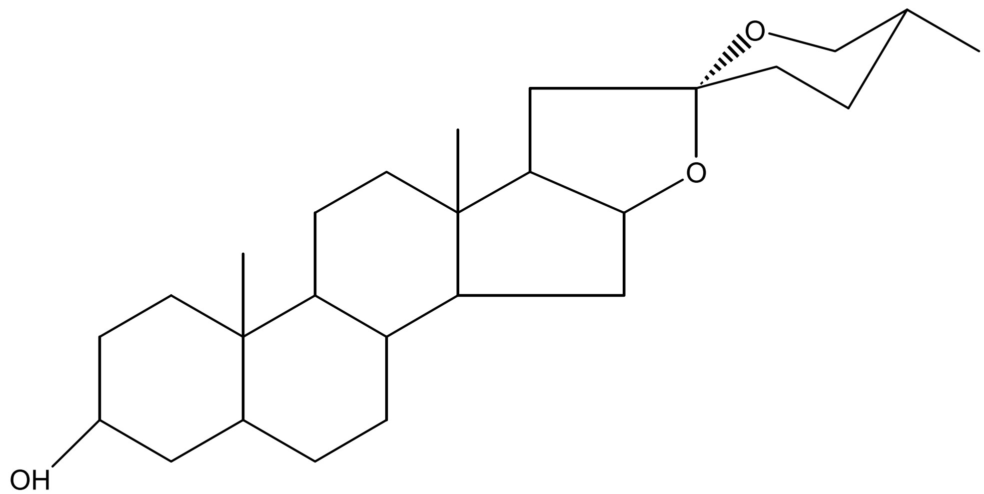


Fig. 2.1: Chemical structure of Quillaja saponin showing the triterpenoid sapogenin nuclei and the bidesmoisdal (two-carbohydrate side chain) nature of Quillaja saponins (Cheeke, 1999).



Smilagenin

Fig. 2.2. Chemical structure of Yucca saponin. The side chain on the Yucca saponin is attached to the hydroxyl group (Cheeke, 1999).

Uses of Yucca and Quillaja extracts

Due to their surface-active or detergent properties, saponins are excellent foaming agents, forming very stable foams (Cheeke, 1999). These extracts may be considered an alternative to other foam-producing agents for effective use in products such as carbonated beverages, teas, schnapps, beer and cocktails (Desert King International, 2004). Yucca and Quillaja saponins are used as natural foaming agents in the production of slush-type drinks (slurpies) and in root beer to provide the foamy 'head'. Because of their surfactant properties, they are used industrially in mining and ore separation, in preparation of emulsions for photographic films, and in cosmetics such as lipstick and shampoo. Their antifungal and antibacterial properties are also important in cosmetic application, in addition to their emollient effects. Quillaja bark has been used as a shampoo in Chile for hundreds of years, and Native Americans used Yucca to make soap. In addition they are currently used as dietary additives for livestock and companion animals, primarily for ammonia and odor control (Cheeke, 1999).

The desert plants *Yucca schidigera* and *Quillaja saponaria* are rich storehouses of phytochemicals with many useful and important functions in human and animal nutrition (Cheeke, 1998). They are also used as natural emulsifiers, flavor enhancers, natural preservatives and in cholesterol reduction. A recent patent granted to the University of California claims that a simple process using food-grade saponins, Quillaja and Yucca, removes up to 83% of the cholesterol from milk, removes up to 77% of cholesterol from cream, and removes up to 80% of the cholesterol from butter oil. Japanese patents have demonstrated that saponins, as natural emulsifiers, help prevent oil separation in mayonnaise, increase the stability of cream when added to coffee, and are natural dispersing agents for waxes used in food coatings (Desert King International, 2004).

Frying

Industries, restaurants and consumers utilize frying as an important method of food preparation. Deep-fat frying is a convenient method of food preparation but increasing consumption of fried foods has led to an increase in obesity and heart-related diseases as well as some cancers.

Deep-fat frying is defined as the process of cooking foods by immersing them in an edible oil or fat which is at a temperature above the boiling point of water, typically 150-200^{o}C (Farkas *et al*., 1996). The process of deep-fat frying uses fats and oils as a heat transfer medium. When the food is immersed in oil, the energy is transferred from the heated element to the fat and then from the heated fat to the cooler surfaces of the product. If the food contains carbohydrates, this contact between hot fat and the food product leads to the formation of a brown crust due to caramelization of the carbohydrate present (Mehta and Swinburn, 2001). Research has shown that the moisture content of the food plays an important role during frying. According to Mehta and Swinburn (2001), the water in potato chips was converted to steam during the frying process; this steam cooked the chips and escaped through the pores of the product due to internal pressure. When the chips were taken out of the fat, they started to cool, leading to a reduction in the production of steam and a reduction in the internal pressure. The voids left by the removal of the water through the pores were then filled with cooking fat, especially in the outer layer. Gamble *et al*. (1987) also reported a correlation of 0.998 between oil content and moisture content of potato chips. In research done by Moreira *et al*. (1997), on the factors affecting oil uptake in tortilla chips in deep-fat frying, initial moisture content significantly affected the final oil content of the tortilla chips. As initial moisture content increased, the final oil content increased. According to Varela (1988), oil absorption occurs as moisture is removed from the food during frying.

Improved public and media awareness of the desirability of reducing the proportion of fat in the average diet has prompted study into means of lowering the oil content of many foods (Gamble *et al*., 1987). Deep-fat frying of foods is a popular way to prepare tasty food quickly, but fried foods contain significant amount of fats, comprising in some cases 1/3rd of the total food product by weight (Mellema, 2003). Oil consumption, especially saturated fat, is recognized as one of the major factors playing a significant adverse role in human health. It is associated with obesity and coronary heart disease (Saguy and Dana, 2002; Mellema, 2003). However, sales in fast foods, which are mainly fried foods, is on the increase. According to Saguy and Dana (2002) in 1970, Americans spent $6 billion on fast foods and the figure grew in 2000 to $110 billion. Hence the consumption of fried foods is on the increase. Frying has also accelerated U.S. acceptance of ethnic foods, bolder flavors and added a crunch to traditional meals (Sloan, 2000).

The consumer's preference for low-fat and fat-free products has been the driving force of the snack food industry to produce lower oil content products that still retain desirable texture and flavor (Garayo and Moreira, 2002). Research has identified several methods of lowering the oil content of foods such as the use of vacuum frying (Garayo and Moreira, 2002), edible films (Williams and Mittal, 1999), and modifiers (Falade *et al*., 2003; Patterson, 2002). These methods showed varied results of lowering the fat content of the foods as well as modifying physical properties of the food, such as texture.

Curdlan

Curdlan is a water-insoluble polysaccharide (β-1, 3 glucan) (Fig 2.3) produced by *Alcaligenes faecalis* var. *myxogenes*, and has a specific character to make an irreversible gel by heating of a water suspension (Harada *et al.*, 1966). In its natural state, curdlan exists as a granule much like that of starch which is insoluble in distilled water, but dissolves easily in dilute alkali solution (Cheeseman and Brown Jr., 1995). An advantage with curdlan is that it is odorless, colorless and tasteless and is indigestible. Curdlan is used as a formulation aid, processing aid, stabilizer and thickener or texturizer for use in food and was approved for these uses by the U.S. Food and Drug Administration (FDA) in December 1996 (FDA, 1996). Approval of curdlan was based on the fact that it consisted of a glucose polymer and a small amount of inorganic salts, mainly sodium chloride; it is non-toxic and the producing organism is also non-pathogenic and non-toxicogenic; and there is a history of safe consumption of similar

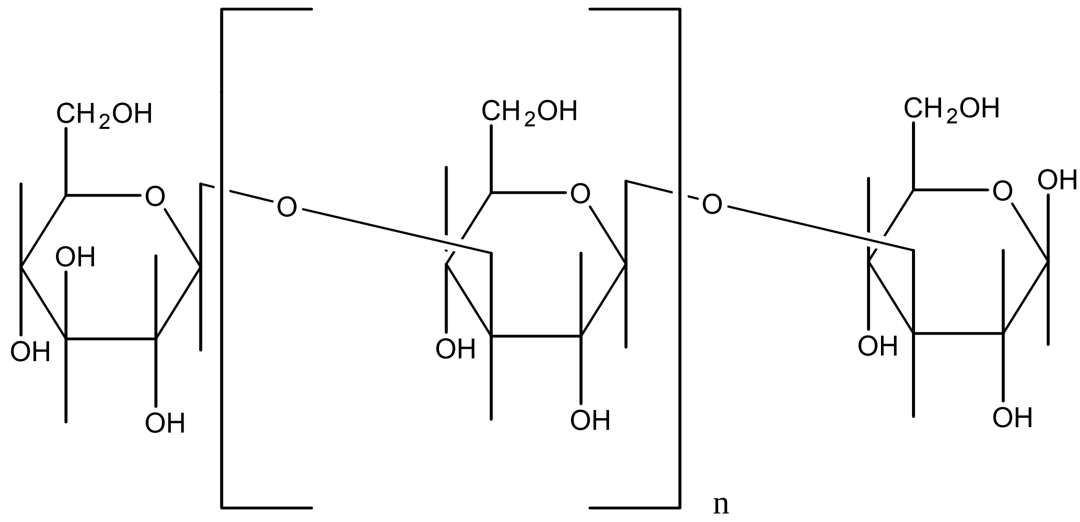


Fig. 2.3. Structure of curdlan

glucose polymers in food (Spicer *et al*., 1999). Depending on the temperature, it forms two types of heat-induced gels: low-set and high-set . The gel is composed mainly of interacting microfibrils which are made up of many curdlan molecules (Cheeseman and Brown Jr., 1995). The low-set gel is thermo-reversible and is obtained when an aqueous dispersion is heated to between 55 and 60^oC and then cooled to 40^oC; the high-set gel is thermo-irreversible, stable at low and high temperatures and obtained when the aqueous dispersion is heated to above 80^oC (Harada *et al*., 1987). The high-set gel has the properties of being much stronger and more resilient than the low-set get. This change is explained by the hypothesis that microfibrils dissociate at 60^oC as the hydrogen bonds are broken, but then reassociate at higher temperatures as hydrophobic interactions between the curdlan molecules occur (Harada *et al*., 1979). Curdlan has an advantage over other gelling agents such as carrageenan, agar-agar, HM pectin, gellan and gelatin gel in that it gels on heating alone whereas these other gelling agents gel after heating, then cooling (Deis, 1997).

According to Funami *et al*. (1999), the thermal gelling properties of curdlan can be considered as a potential oil-barrier-forming ingredient for fried foods. In their research on using curdlan to reduce the oil uptake of doughnuts during deep-fat frying, addition of 0.1-0.5% curdlan significantly decreased the final lipid content and oil uptake of doughnuts. It also significantly increased the final moisture content and decreased moisture loss. Up to 0.5% addition, curdlan also reduced the breaking stress of the doughnuts compared with sodium carboxy methylcellulose (CMC) and methylcellulose (MC) which increased it.

Soybeans

The soybean seed consists of an embryo enclosed by the seed coat. Very little endosperm tissue exists. The embryo is comprised of two cotyledons, a plumule with the two simple leaves, and the hypocotyl-radical axis (Hicks, 1978). Commercial soybeans constitute approximately 8% hull, 90% cotyledon, and 2% hypocotyl and plumule. Oil and protein make up

60% of the bean, with carbohydrate comprising a third of the bean, including polysaccharides, stachyose (3.8%), raffinose (1.1%) and sucrose (5.0%) (Wolf and Cowan, 1971).

History and production

Soybean belongs to the family *Leguminosae*, subfamily *Papilionoideae*, and the genus *Glycine* L. The cultivated form is *Glycine max* (L.) Merrill. This genetic name was given to soybeans by a Swedish botanist named Carl von Linne. *Glycine* is a Greek word meaning 'sweet' and applies to all the groundnut species of legumes; the word *max* means 'large', referring to the large nodules on the soybean plant (Liu, 1997). Soybeans' origin and early history are unknown but they were grown for centuries in the Orient mainly for seeds. These were used in preparation of a large variety of fresh, fermented and dried food products, considered indispensable in the diet of Oriental people. Large quantities of soybeans were crushed to extract the oil for food and industrial purposes. The meal remaining after extraction of the oil was used primarily for fertilizer and as animal feed, especially for cattle (Probst and Judd, 1973).

Early soybean production in the United States was concentrated mainly in the eastern and southern states. Soybeans were introduced to the Eastern United States in the late 1800's. In 1919, the five leading states in acreage were North Carolina, Virginia, Mississippi, Kentucky and Alabama (Probst and Judd, 1973). Production spread to the Midwest by 1920. They were considered primarily as an abundant source of inexpensive edible oil (Orthoefer, 1978). According to FAO, 160 million tonnes of soybean were produced worldwide in 2000 with the U.S.A. as the leading producer (49%), then Latin America and the Caribbean with 34%, Asia (14%) and Africa (<1%). In 2000, 73 million hectares of soybeans were cultivated throughout the world. More than 29 million hectares of this were in the U.S.A., while about 817,000 hectares were in sub-Saharan African (IITA, 2004b).

Processing of soybeans

The utilization of soybeans began in the Orient where both medicinal and food value was assigned to the legume. Various types of foods prepared from it included beverages, pastes, curds and fermented flavorants, some resembling milk, cheese and meal. Processing of soybeans into oil and meal started in relatively recent times (Orthoefer, 1978). There are distinct differences in how the East and the West use soybeans in that in the Far East, traditionally, soybeans are made into various foods for human consumption, whereas in the West, most soybeans are crushed to yield oil and defatted meal. Soybean oil is almost all for human consumption but soy meal is mainly used as animal feed. Only a small portion is processed into soy protein ingredients including soy flour, concentrates, isolates, and textured soy proteins which have functional and nutritional applications in bakery, dairy, meat products, infant formulas and soy foods (Liu, 1997). Modern technology has been developed to allow for the processing of soybean into full-fat flour, defatted flour, protein isolate, protein concentrate, texturized soy protein and spun soy protein (Circle and Smith, 1972).

Processing of soybeans removes the oil which is used by the edible fat industry and converts the defatted meal into feeds and food products. For food uses, processing may consist of merely heating and grinding the defatted material as in the preparation of flours and grits (Wolf and Cowan, 1971). Flour, grits and meal are produced by mechanically removing the hull, followed by extraction of the oil with hexane. Residual hexane is removed by either indirect heating followed by steam sparging in a desolventizer-toaster (to make meal) or by direct contact with super-heated hexane in a flash desolventizer. The desolventized soy is heat-processed, ground, and segregated to the desired particle size distribution according to product specification. The distinction between flour, grits and meal is due primarily to the particle size range of the product (Potter and Jones, 2003). Defatted flours, which contain 52-54% protein, are prepared by finely grinding defatted flakes to pass through a no. 100 U.S. standard screen.

The flour is used in a variety of food applications where a wide range of protein solubilities is required (Rhee, 1994).

Nutritional quality of soybeans

Soybean is an important source of high quality but inexpensive protein and oil. With an average protein content of 40% (of total dry matter) and oil content of 20%, soybean has the highest protein content of all food crops, and is second only to groundnut in terms of oil content among food legumes (IITA, 2004b). Soybean is cheaper compared to other protein-rich foods such as meat, fish and eggs. The proximate composition of raw soybeans and soybean products is shown in Table 2.3. Based on human requirements, the essential amino acids are equal to or exceed levels found in egg protein except for the sulfur-containing amino acids. Methionine is the first limiting amino acid. Soybean has a high lysine content compared to most other plant proteins (Orthoefer, 1978), which places soybean protein in a distinct class of vegetable proteins. Lysine is limiting in most cereal proteins, thus it is possible that soy protein may be able to improve total protein status in populations dependent on cereal grains for food (Nwokolo, 1996). Table 2.4 shows the amino acid content of soybean and soy products. The protein in soybean is highly digestible (92-100%) and contains all of the essential amino acids (Riaz, 1999).

Soybeans contain about one-third carbohydrates (water-soluble and water-insoluble), which vary with environmental and varietal differences. Defatted soybean flakes contain about 11.6% total soluble sugars. The principal sugars consist of 5% sucrose, 1.1% raffinose, and 3.8% stachyose (Orthoefer, 1978).

Health benefits of soybeans

There is an increasing use of soybean in functional foods because of its numerous health benefits. Soy proteins have been shown to improve coronary heart health, reduce cholesterol levels, reduce the risk of cancer and reduce menopause symptoms, among others.

Table 2.3. Proximate composition of soybean and soy products (g/100g)

Constituents	Raw soybean	Defatted flour	Protein concentrate	Protein Isolate
Water (g)	8.54	7.25	5.80	4.98
Food energy (kcal)	416	329	332	338
Protein (g)	36.49	47.01	58.13	80.69
Lipids (g)	19.94	1.22	0.46	3.39
Carbohydrate (g)	30.16	38.37	31.21	0.36
Crude fiber (g)	4.96	4.27	3.77	0.26
Ash (g)	4.87	6.15	4.70	3.58

Source: USDA (1986)

Table 2.4. Amino acid content of soybean and soy products (g/100g)

Amino acids	Raw soybean	Defatted flour	Protein concentrate	Protein Isolates
Tryptophan (g)	0.53	0.68	0.83	1.11
Threonine (g)	1.58	2.04	2.47	3.13
Isoleucine (g)	1.77	2.28	2.94	4.25
Leucine (g)	2.97	3.82	4.91	6.78
Lysine (g)	2.42	3.12	3.92	5.32
Methionine (g)	0.49	0.63	0.81	1.13
Cysteine (g)	0.58	0.75	0.88	1.04
Phenylalanine (g)	1.90	2.45	3.27	4.59
Tyrosine (g)	1.38	1.77	2.30	3.22
Valine (g)	1.82	2.36	3.06	4.10
Arginine (g)	2.83	3.64	4.64	6.67
Histidine (g)	0.98	1.26	1.57	2.30
Alanine (g)	1.71	2.21	2.68	3.59
Aspartic acid (g)	4.58	5.91	7.24	10.20
Glutamic acid (g)	7.06	9.10	12.01	17.45
Glycine (g)	2.13	2.75	3.29	4.96
Proline (g)	2.13	2.75	3.29	4.96
Serine (g)	2.11	2.72	3.36	4.59

Source: USDA (1986)

Soybean has been found to be hypocholesterolemic. The cholesterol-lowering effect of soy ingredients has been attributed to isoflavones, a class of phytochemicals found in them (Potter, 1998). Soy protein drinks that contain naturally-occurring high levels of isoflavones reduce total cholesterol and LDL cholesterol ('bad' cholesterol) in patients who had high cholesterol levels despite consuming a low-fat, heart-healthy diet. Several studies promote the cholesterol-lowering effects of soy protein as a weapon in the fight against coronary heart disease. The incidence of coronary heart disease is lower in nations consuming soy products as a major component of the diet (Riaz, 1999). Anderson *et al*. (1995a), states that every 1% reduction in cholesterol values is associated with an approximate 2-3% reduction in the risk of coronary heart disease. Despite all the evidence that points to the role of soy protein in lowering blood cholesterol, one of the major contributors to coronary disease, soy remains a very small part of the diet of people in the Western world, where coronary disease is a leading killer (Riaz, 1999).

It is well known that Asian women, who typically eat a soy-based diet, have a much lower incidence of breast cancer than Western women. Daidzein and genistein are the two primary isoflavones found in soybeans. These compounds may reduce the risk of a number of cancers including those of the breast, lung, colon, rectum, stomach, and prostate. Genistein appears to be less bioavailable than daidzein and is thought to act against cancer by interfering with cancer-promoting enzymes, by blocking the activity of hormones in the body and even by interfering with the process by which tumors receive nutrients and oxygen (Broihier, 1997). Genistein is found in soy, clover, and only a few other green plants, however, soy-based foods represent the only practical way consumers can incorporate genistein in their diet. As long as isoflavones are present, any type of soy food- soymilk, tofu, tempeh, textured vegetable protein or whole soybeans- may offer cancer-prevention benefits (Riaz, 1999).

Studies also indicate that consuming soy isoflavones may reduce the frequency and intensity of hot flashes in menopausal women. The improvements in menopausal symptoms are attributed to phytoestrogenic factors in soybeans. Soy foods may also help prevent and treat osteoporosis. Osteoporosis causes bones to become overly porous and brittle from loss of calcium and other minerals (Riaz, 1999). Genistein and daidzein, isoflavones found in significant amounts only in soybean and soy foods, may directly inhibit bone resorption (Anderson *et al*., 1995b).

Increasing the protein content of akara by partial substitution of cowpea flour with soybean flour

In recent times more and more people are following the 'low-carb diet' which is a diet based mainly on proteins and aims to reduce a large percentage of carbohydrates from the diet. Meats and produce are a major part of this diet which, according to a recent article by Golden (2004), can put a strain on pocket books. This is because according to this article, the Food Marketing Institutes 2004 Trends Report states that a one-person household spends on average $59 a week on groceries, but to follow a low-carb meal plan, that cost jumps to $99.89 for the Atkins Diet and $91.28 for the South Beach Diet. This almost doubles the grocery cost. As a result the national health interview study shows that 26% of those with income less than $17,000 are overweight compared to 18% for those making over $67,000 per year. So for those on a limited income, a diet consisting primarily of animal proteins causes a financial strain.

Cowpeas and soybeans are a source of low-cost, high quality protein. A diet consisting of these will put less strain on the pocket book and will provide the body with essential amino acids. Supplementing cowpea with soybeans improves the protein content of a product due to the high protein content of both of these legumes. As with all legumes, the limiting amino acids in these legumes are the sulfur-containing amino acids. However, soybeans contain higher levels of these amino acids than cowpeas. According to Young (1991), the level of sulfur-containing amino acids in soy is sufficiently high so that soy protein is able to meet human protein needs by itself when consumed at the recommended level of protein intake. As a result, supplementing a percentage of the cowpea flour in akara with soybean flour will improve the nutritional quality of akara as well as increase the levels of methionine and cysteine, and provide consumers with a source of low-cost protein. Calculations done with a Food Processor software® (ESHA Research, 1997) showed that substitution of 20% cowpea flour with soybean flour in the preparation of akara (80g cowpea flour + 20g soybean flour) gives a protein quality score of 100% (based on the limiting value of methionine and cysteine in soybeans and cowpeas). This protein quality score was obtained for comparison of the protein content of the akara with the protein requirements of an American child (1-3 years). A study done by Falade *et al*. (2003) on the effect of soybean substitution for cowpea on physical, compositional, sensory and sorption properties of akara Ogbomoso (fried, unwhipped cowpea paste product) showed that the protein content of the product increased with a corresponding decrease in the carbohydrate content. There was also an improvement in the protein quality of the product due to addition of the soybean flour.

Reducing the fat content of akara by partial substitution of cowpea flour with soybean flour

Studies have shown that addition of soybean flour to fried food formulations plays a role in reducing the oil uptake of the product during frying or on the overall fat content. Significant reductions in oil absorption with incorporation of soybean flour have been achieved for various food products (Mohamed *et al*., 1995; Johnson, 1970; Martin and Davis, 1986; Wolf and Cowan, 1971; Huse, 1996).

In a study done by Huse (1996) on the effect of formulations and edible coatings on oil absorption and consumer acceptance of a cowpea-based fried product, it was observed that soy flour incorporated into akara formulations at 6% substitution level significantly reduced oil absorption during deep-fat frying by 26% compared to the control. The exact mechanism by which soy flour protein reduces oil absorption is not completely understood. However, this study postulated that it is due in part to changes in specific gravity and foaming ability of the akara paste. Addition of soy flour to the cowpea flour significantly reduced the foaming ability of the cowpea paste, which may be due to the fact that the mild heat treatment of the soybeans has an effect on protein solubility. As a result, there were reduced air spaces in the fried product, and hence less oil was absorbed.

Fractionation and characterization studies of soluble protein extracts (Bicinchoninic acid protein assay) of akara (0%, 6% and 100% soy) was done to help explain the ability of soy flour in reducing fat absorption. In 100% cowpea akara, soluble protein contents of all fractions decreased initially from 42-36.5% after a minute of frying then leveled off at 35% for up to a total frying time of 4 min. For 6% soy akara (94% cowpea), soluble protein decreased across all protein fractions at a more rapid rate than observed in 100% cowpea akara. For 100% soy akara, levels of soluble protein fractions increased from 1.3% to 1.5% after one minute of frying then decreased to 0.6% after 4 min of frying. Thus increasing the soy flour substitution increased the rate of soluble protein denaturation, leading to the conclusion that the increase in protein denaturation and increased rate of denaturation could also account for reduced oil absorption in soy-substituted products. Studies done by Wolf and Cowan (1971) and Mohamed *et al*. (1995) hypothesized that the decrease in oil absorption may be related to the rate of denaturation of the protein, and that the denatured proteins form a fat-resistant barrier.

In the present study, Quillaja and Yucca saponins were used to increase the foaming capacity of cowpea paste, thereby improving the texture of the fried product (akara). In the second part of the study soy flour and curdlan were used to reduce oil absorption, reduce the overall fat content of akara, and also enhance its protein content. The moisture content of paste containing 20% soy flour and 1% curdlan was modified in the third study to obtain product characteristics similar to the control. Success in these objectives will result in a product that is more acceptable to Western cultures and will provide consumers with a product that is not only low in fat but has enhanced physical and nutritional qualities.

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CHAPTER 3

EFFECT OF SAPONINS ON THE PHYSICAL CHARACTERISTICS, COMPOSITION AND QUALITY OF AKARA (FRIED COWPEA PASTE) MADE FROM NON-DECORTICATED CREAM COWPEAS[1]

[1]M. A. Plahar, Y.-C. Hung, K. H. McWatters, R. D. Phillips and M. S. Chinnan. Submitted to Lebensmittel-Wissenschaft und-Technologie.

ABSTRACT

Changes in the foaming capacity and viscosity of cowpea paste, effected by the addition of saponins, were investigated, as well as the subsequent effect on the texture and oil content of Akara (fried cowpea paste). Two saponins, Quillaja and Yucca, were used. Results showed a significantly greater decrease in the specific gravity after whipping (39.9-52.9%) of the paste prepared with saponins compared to that prepared without saponins (25.1-32.9%). This demonstrated the increase in foaming capacity of the paste prepared with saponins. The results also showed a higher foaming capacity for the Yucca saponin compared with the Quillaja saponin. Subsequently, there was a significant decrease in the apparent viscosity of the paste prepared with saponins and a decrease in the firmness (6.51-7.78 N) of the fried product compared to that prepared without saponins (10.89-11.58 N). These results suggest that saponins can be used to increase the foaming capacity of cowpea paste resulting in a more desirably soft, spongy-textured product. There was a significant increase in the fat content of the samples produced with saponins (25.13-42.03%) compared to the control (18.81-19.65%) due to the formation of more air spaces in the cowpea paste.

Key words: cowpea paste, akara, texture, foaming, viscosity, saponins, quillaja, yucca

INTRODUCTION

Cowpea (*Vigna unguiculata*) is a rich source of protein (24%) and B-vitamins (Phillips & McWatters, 1991). It is a primary food legume in West Africa, with more than 80% being produced in that region of the world (Patterson, 2002). In the United States, legume consumption is extremely low (5g/day) whereas legumes provide half or more of the dietary protein in developing countries (Phillips, 1997). About 10-150g/day of legumes is consumed in India and Sub-Saharan Africa and 50-89g/day in Latin America (Bressani, 1985). The difference in consumption between developing and developed countries is the lack of modern food technologies for converting legumes to attractive, convenient foods. Beans are generally boiled over fire and eaten as is. Western food processors need to develop technologies to convert legume seeds to tasty, nutritious foods which will be accepted by the developed countries (Phillips, 1997).

Akara is a food prepared by whipping cowpea meal with water, mixing with bell or hot pepper, onion and salt, and deep fat frying (Misra, Fletcher & McWatters, 1996). This cowpea product is indigenous to Ghana, Nigeria and other West African and South American countries. Akara is similar to a fried cornmeal product (hush puppies) indigenous to the southern part of the United States of America. It has a spongy interior and a crisp outer layer. Akara represents a nutritious alternative to hush puppies because according to McWatters, Resurrecion, Fletcher, Peisher & Andress (1993), the protein content of akara (dry weight basis) is 22% compared to 10% for cornmeal hush puppies and 8% for French fried potatoes.

Akara has been introduced to the American public by the Department of Food Science and Technology of the University of Georgia where there is ongoing research into developing this product to suit the needs of the American public. In West African countries, akara is prepared using a tedious method of soaking, decortication and milling of the cowpeas, however, a more convenient method of preparation involves the use of a ready-to-use cowpea meal. To improve the appearance of the product by elimination of the black-eyes, a cream-type cultivar (breeding line UCR 97-15-33) can be used without decortication to prepare the meal. The beans are coarsely milled using a 2.54 mm screen to retain the water holding capacity of the seeds and hence the foaming capacity of the cowpea paste.

A very important factor in the acceptability of akara is the texture. According to Enwere, McWatters & Phillips (1998), the spongy texture of akara is highly desirable and constitutes a strong factor in determining the acceptability of akara balls among Nigerian consumers. In a study done by McWatters (1983), akara made from Nigerian cowpea flour was less desirable than that made traditionally because the akara made from flour was described as 'dry, dense, and having a tough outer surface'. Traditionally prepared akara was described by Kethireddipalli, Hung, McWatters & Phillips (2002a) as 'spongy and tender'. As such the texture of akara is very important and determines its acceptability to a large extent.

The foaming capacity of cowpea paste is very crucial in developing a product with the textural characteristics associated with akara (Kethireddipalli, 1999). Foam consists of an aqueous continuous phase and a gaseous (air) dispersed phase. The unique textural properties and mouthfeel of foam-type products stem from the dispersed tiny air bubbles (Damodaran, 1994). The factors affecting foaming ability of cowpea paste include particle size, hydration time, protein content, and protein solubility. The high protein content (24%) of cowpea contributes to its foaming capacity (Bressani, 1985). Modification of the foaming capacity of the paste will modify the texture of the end product. Increased foaming capacity will result in an increased gaseous dispersed phase leading to increased air spaces in the product, hence a product with 'lighter' texture. According to McWatters, Chinnan, Hung & Branch (1988), the production of akara balls with uniform shape, color, and texture depends upon the functionality (hydration, foam and flow characteristics) of minor cowpea proteins. The functional properties of proteins (in legumes) may be altered by physical, chemical, or biological means (Pour-El, 1981). A means by which this can be achieved is the use of saponins in akara making.

Saponins are glycosidic compounds composed of a steroid (C–27) or triterpenoid (C-30) saponin nucleus with one or more carbohydrate branches. Figures 2.1 and 2.2 show the chemical structures of the Quillaja and Yucca saponin, respectively. The Quillaja saponin has a triterpenoid sapogenin nucleus with two carbohydrate side chains; the Yucca saponin has a steroidal sapogenin nucleus with a side chain attached to the hydroxyl group (Cheeke, 1999). Saponins have a distinct foaming characteristic (Anonymous, 2004). The foaming capacity of saponins is due to their content of both water-soluble and fat-soluble molecular moieties (Dinan, Harmatha & Lafont, 2001). Quillaja and Yucca saponins have been used in foods, especially in beverages, to increase their foaming capacity. They are heat stable, pH stable from 2.5-8, and approved for human consumption by the joint WHO/FAO, USA-FDA, European community (E999), and Japan; FEMA [GRAS number 2973 (Quillaja saponin) and 3121 (Yucca saponin)].

In a study done by Park, Plahar, Hung, McWatters & Eun (2004) to investigate the effect of saponins on the foam/flow properties of paste made from decorticated black-eyed cowpeas, results show that the two saponins used, Quillaja and Yucca, were effective in increasing the foaming capacity of the black-eyed cowpeas. This also resulted in a decrease in the firmness of the fried product (akara) and an increase in the brownness of the color as compared to the control. Production of flour from black-eyed cowpeas is labor-intensive and time-consuming because the cowpeas have to be soaked in water, dried, and decorticated to remove the dark seed coats prior to dry milling. Research with different cowpea cultivars has shown that cream peas, which have white seed coats and no dark pigmentation, produce paste with acceptable processing performance and sensory quality, without the need to dehull the peas (McWatters & Flora, 1980; McWatters & Brantley, 1982; McWatters, 1983; Patterson, 2002).

Hence the objective of this study was to investigate the effect of two saponins [Quillaja (Quillaja extract) and Yucca (Foamation “R”)] on the foaming capacity of paste made from non-decorticated cream cowpeas and investigate:

1. Their effect on the quality of akara and

2. The effect of an increase in the foaming capacity on the oil uptake/fat content of the fried product.

Addition of 1% saponin to the non-decorticated cream cowpeas corresponded to the addition of 2% saponin to decorticated black-eyed cowpeas in the research done by Park *et al.* (2004).

MATERIALS AND METHODS

Cowpea flour production

Dry cowpea seeds (breeding line UCR 97-15-33) (Fig 3.1) were obtained from Inland Empire Foods, Inc. (Riverside, California) and stored at 2°C until used. These cream-type seeds were milled into flour (Fig 3.2) without decortication using a hammer mill (Champion, Model no. 6X14, Champion Products Inc., Eden Prairie, Minnesota) equipped with a 2.54 mm screen.

Saponins

Yucca and Quillaja saponins (Fig 3.3) were obtained from Desert King International (Cincinnati, Ohio). Their properties are described in a related study by Park, Plahar, Hung, McWatters & Eun (2004).

Fig 3.1. California cream peas

Fig 3.2. Cowpea flour

Fig 3.3. Quillaja and Yucca saponins

The foam stability of the saponins was determined by adding 1 ml of saponin solution (1 g saponin + 9 g distilled water) to 350 ml distilled water in a graduated cylinder (250 x 7.7 cm). The graduated cylinder was covered with Parafilm and shaken vigorously 30 times. The initial foam height was measured in ml after 30 sec and the final foam height measured after 30 min. The percent foam stability was calculated as follows:

% foam stability = (final foam height in ml / initial foam height in ml) x 100 (Desert King International, 2004).

Using this method, the foam stability of Yucca and Quillaja saponin were both 87%. Visual observation of the foam produced by these saponins showed that the Quillaja saponins produced larger air bubbles than the Yucca saponin.

Cowpea paste preparation

Cowpea paste was prepared by adding 116 g of water and 1% (based on 216 g paste) saponin to 100 g of the cowpea flour. The mixture was stirred gently with a rubber spatula and then allowed to stand for 15 min (Fig 3.4). The resulting paste was whipped for either 1.5 or 3 min in a household mixer (Model 2366, Sunbeam Corp., Delray Beach, Florida) at speed 12 (high) (Fig 3.5). During whipping, a rubber spatula was used to continuously scrap off the

Fig 3.4. Cowpea paste allowed to stand for 15 min.

Fig 3.5. Whipping of cowpea paste

paste that adhered to the sides of the mixing bowl to ensure effective mixing. After whipping, appropriate amounts of chopped bell peppers, chopped onions, and salt (for each 216 g cowpea paste, 9.5% bell peppers, 9.5% onions, and 1.5% salt) were manually folded into the paste with a rubber spatula before frying.

Apparent viscosity and specific gravity measurements

The apparent viscosity of the cowpea paste was determined at 23°C after whipping (before adding peppers, onions, and salt) with a digital viscometer (Model HATD, Brookfield Engineering Laboratories, Inc., Stoughton, Massachusetts) (Fig 3.6). Whipped cowpea paste (250 ml) was poured into a 600 ml beaker and tapped 10 times on the heel of the palm to remove any air pockets. An inbuilt leveler was used to level the instrument. Measurements were made at 10 rpm using a T spindle (number C) with a cross bar length of 1.064 in (27.1 mm). Readings were taken continuously for the same sample as the spindle was immersed to a depth of 2.5 cm and returned to the surface (total distance = 5 cm). The readings were recorded by a recorder attached to the viscometer. The readings were read off a graph and the average taken. The apparent viscosity (Pa.s) was calculated by the following formula:

Viscosity in Pa.s = spindle factor x viscometer reading x 10^{-3}

Spindle factor = 20 M/rpm

M = 1000, rpm = 10

Specific gravity was measured (before and after whipping without peppers, onions, and salt) using three 0.25 cup size (~60 ml) U.S. standard dry measuring cups as described in Park *et al.* (2004).

Akara preparation

Depending on the sample, whipped paste with additional ingredients was dispensed into hot (193°C) peanut oil in an atmospheric fryer (Kitchen Kettle™ electric multi-cooker, National Presto Industries, Eau Claire, Wisconsin) using a #40 ice cream scoop (~20 ml) and fried for 3 min (1.5 min on either side) (Fig 3.7). The fried akara balls were then drained on absorbent paper towels (Fig 3.8), cooled to room temperature, counted, weighed (5 samples per batch), and used for texture and color measurements.

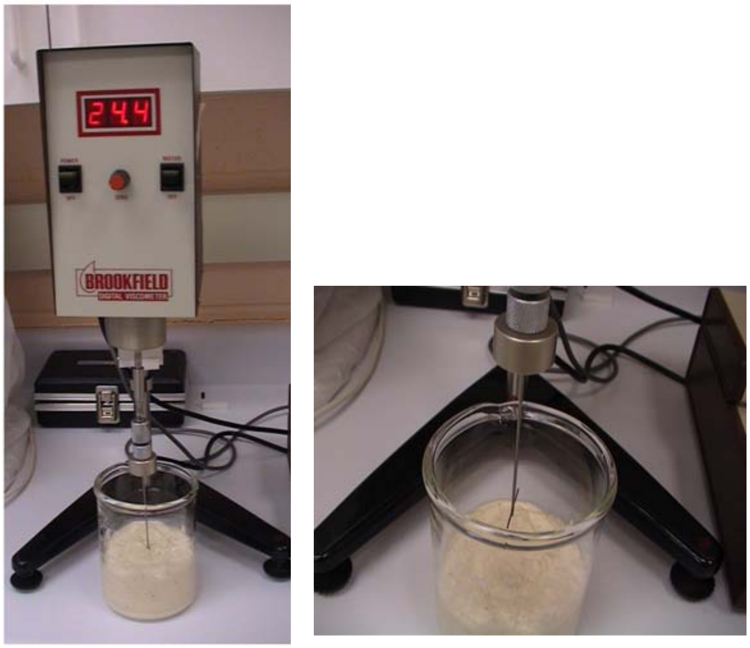

Fig 3.6. Measurement of apparent viscosity

Fig 3.7. Frying

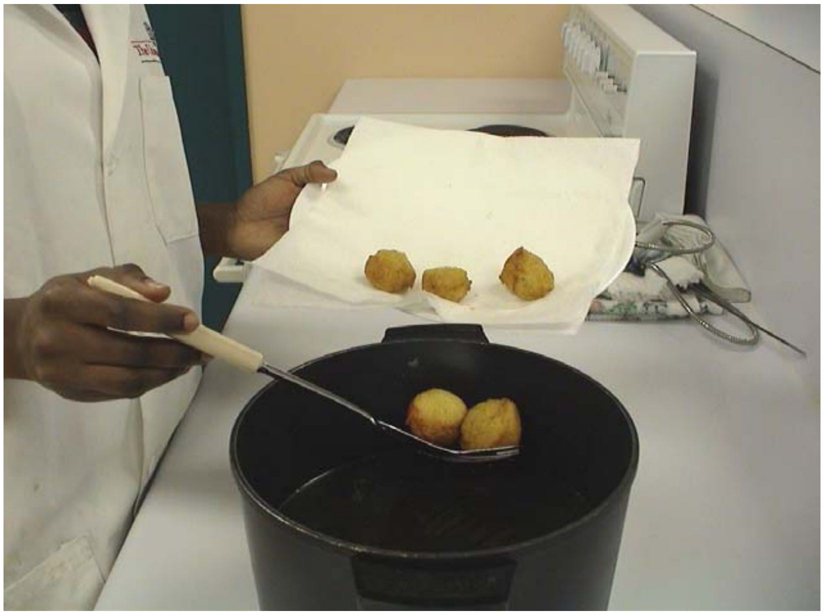

Fig 3.8. Fried cowpea paste (akara)

Color measurement

Hunter color values (L*, a*, b*) of the akara balls were measured using a Minolta colorimeter (Model CR-200, Osaka, Japan) calibrated with a brown reference tile (L* = 69.82, a* = 19.17 and b* = 31.75). Five akara balls from each batch were measured. Each ball was measured twice, once on each side. Hue angle was calculated as $\tan^{-1}(b^*/a^*)$, chroma as $(a^{*2}+b^{*2})^{½}$ and total color difference (ΔE) as $[(L^*-L^*reference)^2 + (a^*-a^*reference)^2 + (b^*-b^*reference)^2]^{½}$.

Texture measurement

The texture of the same akara balls used for the color measurements was determined using an Instron universal testing machine (Model 5544, Instron, Inc., Canton, Massachusetts) fitted with a 2000 N load cell. A cube of 1 cm was cut from the crumb portion of the akara ball and compressed twice in reciprocating motion each time to 25% of its original height at a crosshead speed of 50 mm/min (Kethireddipalli *et al*., 2002a). Peak heights were measured and the force required to shear was reported as Newtons per gram (N/g). Firmness, cohesiveness, Chewiness, and springiness data were obtained as follows: Firmness= force necessary to attain a given deformation (Newtons); Cohesiveness= the strength of the internal bonds making up the body of the product (ratio of positive force areas under first and second compressions); Springiness= distance over which the sample recovers its height between the end of the first bite and the start of the second bite; and Chewiness= firmness x cohesiveness x springiness.

Proximate analysis

The moisture content of akara samples was determined by grinding and vacuum drying at 70°C for 24 h [American Association of Cereal Chemists (AACC), 1976; Method 44-40]. The fat content was determined by extraction with petroleum ether for 24 h in a Goldfisch apparatus (Labconco, Kansas City, Mo.) (AACC, 1976, Method 30-26). The samples used for fat extraction were free of moisture and were made more porous by freeze drying. Ash content was determined by using the moisture-free and fat-free samples (AACC, 1976, Method 08-01). Protein content was determined by the nitrogen combustion method (LECO, FP-2000, Warrendale, Penn.), using moisture-free and fat-free samples. The nitrogen content was then multiplied by a factor of 6.25 to obtain the protein content [Food and Agriculture Organization of the United Nations (FAO), 1970]. The carbohydrate content was determined by subtracting the sum of ash, fat, and protein content from 100%.

Statistical analysis

All data were analyzed using analysis of variance (ANOVA) procedures from the Statistical Analysis System (SAS). Mean comparisons were performed using Duncan's Multiple Range Test (SAS, 2000).

RESULTS AND DISCUSSION

Specific gravity

Specific gravity can be used as a convenient index of foaming capacity. The greater the amount of air incorporated into a mixture (*e.g*. egg white foam, creamed shortening and sugar, or cake batter), the lower will be its specific gravity (Campbell, Penfield & Griswold, 1979). The reduction in paste specific gravity after whipping is, therefore, a good measure of foaming capacity (McWatters, Hung, Hung, Chinnan & Phillips, 2001).

Table 3.1 shows calculated values of specific gravity. The values for the 6 samples after whipping were all significantly different. The addition of the two different saponins resulted in a significantly greater decrease in the specific gravity upon whipping, compared to control samples. This is because the saponins have distinct foaming characteristics. Samples prepared with tap water (control) showed a lower reduction in specific gravity (25.11-32.86%) compared with those prepared with the Quillaja saponin (39.93-48.69%) and Yucca saponin (41.98-52.91%).

Proteins are long chain molecules made up of amino acid units. Some parts of the protein molecule are hydrophobic, other parts hydrophilic. The molecule can therefore unfold at a bubble interface, such that the hydrophilic portions are in the water and the hydrophobic portions in the air. Proteins thus stabilize bubbles primarily by forming a rigid system of inter-linked proteins at the interface (Campbell & Mougeot, 2000). Yucca saponin produces an average foam height of 120 ml with small foam bubbles whereas Quillaja saponin produces a higher foam height of 160-180 ml with large foam bubbles (Desert King International, 2004). This data was confirmed by laboratory trials using a 1000 ml graduated cylinder (44.5 X 6.6 cm). Thus it is expected that addition of Quillaja saponin would result in a lower specific gravity than Yucca. However from Table 3.1, samples with Yucca saponin had a lower specific gravity after whipping compared with samples that had Quillaja saponin (0.59 versus 0.61 for 1.5 min whipping and 0.49 versus 0.52 for 3 min whipping). According to Campbell & Mougeot (2000),

Table 3.1
Effect of saponins and whipping time on specific gravity and apparent viscosity of cowpea paste[1]

Sample[2]	Specific gravity before whipping ±SD	Specific gravity after whipping ±SD	Reduction in specific gravity (%) ±SD	Apparent viscosity (Pa.s) ±SD
C + 1.5 WH	1.05±0.02 [a]	0.78±0.01 [a]	25.11±1.44 [f]	125.20±0.00 [a]
C + 3 WH	1.05±0.02 [a]	0.71±0.03 [b]	32.86±2.38 [e]	93.60±0.01 [b]
Ys + 1.5 WH	1.02±0.01 [b]	0.59±0.02 [d]	41.98±1.95 [c]	63.20±0.00 [c]
Ys + 3 WH	1.04±0.02 [a]	0.49±0.02 [f]	52.91±2.08 [a]	53.30±0.00 [c]
Qs + 1.5 WH	1.02±0.03 [b]	0.61±0.03 [c]	39.93±3.29 [d]	67.00±0.01 [c]
Qs + 3 WH	1.02±0.03 [b]	0.52±0.03 [e]	48.69±4.05 [b]	61.00±0.00 [c]

[1]Mean values in a column not followed by the same letter were significantly different (α=0.05).
[2]Qs= paste with Quillaja saponin, Ys= paste with Yucca saponin, C= control and WH is whipping time in minutes.

bubbles will burst or coalesce if the interface thins excessively, thus the lower specific gravity of the paste containing the Yucca saponin may be due to bursting of the large air bubbles produced by it during whipping. According to Kinsella (1979), a high reduction in specific gravity is an indicator of (good foaming power and) foam stability. The higher reduction in specific gravity of the Yucca saponin indicates that the foam produced by this saponin may be more stable in the cowpea paste than that produced by the Quillaja saponin. These results indicate that the paste obtained from non-decorticated cream cowpeas exhibited similar foaming properties compared to the paste obtained from decorticated black-eyed cowpeas prepared under similar conditions of saponin level and whip time (Park *et al.*, 2004).

Whip time also had an effect on lowering the specific gravity. Whipping is important because it incorporated air into the paste. From Table 3.1, the longer whip time (3 min) resulted in a lower specific gravity of the paste after whipping than when pastes were whipped for shorter time. For the Quillaja saponin, a whip time of 3 min resulted in a 48.69% reduction in specific gravity compared with a 39.93% reduction for 1.5 min whip time.

Apparent viscosity

Viscosity is an indication of resistance to flow. An increase in foaming capacity leading to incorporation of air will result in a lower resistance to flow. Table 3.1 shows the apparent viscosities of the 6 samples. Samples containing the saponins had significantly lower viscosities (53.3-67.0 Pa.s) than those without saponins (93.6-125.2 Pa.s). This supports the results obtained for the reduction of specific gravity. A higher foaming capacity resulted in lower apparent viscosity values. Thus the control which had no saponins had the lowest reduction in specific gravity and hence the highest apparent viscosity.

The apparent viscosity of the pastes containing Yucca saponin was lower than that obtained for pastes containing the Quillaja saponin (63.2 versus 67.0 Pa.s for 1.5 min whip time and 53.3 versus 61.0 Pa.s for 3 min whip time). However, this difference was not statistically significant. The difference obtained for the two whip times was also not significantly different.

Apparent viscosities of the paste made from the non-decorticated cream cowpeas used in this study were higher than that obtained in a related study for the decorticated black-eyed peas (Park *et al.*, 2004). This may be due to the presence of fiber material from the seed coat of the non-decorticated cream cowpeas. According to Kethireddipalli *et al.* (2002b), dry-milling of cowpeas increased soluble protein but adversely affected paste viscosity and functionality.

Texture

According to McWatters *et al.* (1988), the foaming capacity of cowpea paste is significant in determining the textural quality of akara. The maximum force required to compress the fried samples was significantly lower for the samples containing saponins (6.51-7.78 N) than the control (10.89-11.58 N) (Table 3.2). The addition of saponins, which resulted in an increase in the foaming capacity of the paste, had an effect on softening the texture of the fried product.

The firmness of the samples containing the Yucca saponin at 1.5 and 3 min whip time as well as the sample containing the Quillaja saponin at 1.5 min whip time was not significantly different (7.68,7.78,7.73 N, respectively) from each other. However, the firmness of the sample containing the Quillaja saponin at 3 min whip time was significantly different from the other samples. This sample was softer (6.51 N), which could be due to the increase in whip time from 1.5 min to 3 min. An increase in whipping time resulted in an increase in the amount of air incorporated into the paste, thus resulting in a softer-textured fried product. Compared to the results obtained by Park *et al.* (2004), the non-decorticated cream cowpeas produced akara that was less firm on addition of 1% Yucca saponin than akara produced from decorticated black-eyed cowpeas (corresponding to 2% Yucca saponin). On addition of 1% Quillaja saponin, the non-decorticated cream cowpeas produced akara balls that were firmer than those produced from the decorticated black-eyed peas (2% Quillaja saponin).

Cohesiveness is the extent to which a material can be deformed before it ruptures (Civille & Szczesniak, 1973). Table 3.2 shows that the control sample at 3 min whip time and the sample containing Yucca saponin at 1.5 min and 3 min whip time had higher cohesiveness

Table 3.2
Effect of saponins and whipping time on the texture of akara[1]

Sample[2]	Firmness (N)[3] ±SD	Cohesiveness[4] ±SD	Springiness (mm)[5] ±SD	Chewiness (N.mm)[6] ±SD
C + 1.5 WH	11.58±1.33 [a]	0.17±0.06 [bc]	0.60±0.03 [abc]	1.18±0.33 [ab]
C + 3 WH	10.89±1.14 [a]	0.22±0.06 [ab]	0.60±0.04 [abc]	1.42±0.28 [a]
Ys + 1.5 WH	7.68±0.61 [b]	0.23±0.02 [a]	0.61±0.03 [ab]	1.09±0.14 [b]
Ys + 3 WH	7.78±0.96 [b]	0.19±0.06 [abc]	0.61±0.03 [a]	0.94±0.15 [bc]
Qs + 1.5 WH	7.73±0.94 [b]	0.17±0.02 [bc]	0.59±0.03 [bc]	0.79±0.11 [cd]
Qs + 3 WH	6.51±0.92 [c]	0.15±0.02 [c]	0.58±0.03 [c]	0.63±0.19 [d]

[1]Mean values in a column not followed by the same letter were significantly different (α=0.05).
[2]Qs= paste with Quillaja saponin, Ys= paste with Yucca saponin, C= control and WH is whipping time in minutes.
[3]Firmness= force necessary to attain a given deformation (Newtons)
[4]Cohesiveness= the strength of the internal bonds making up the body of the product (ratio of positive force areas under first and second compressions)
[5]Springiness= distance over which the sample recovers its height between the end of the first bite and the start of the second bite.
[6]Chewiness= firmness x cohesiveness x springiness

values (0.22, 0.23 and 0.19, respectively) than the rest of the samples. This is an indication that these samples were less crumbly and as a result were not deformed as quickly as the other samples. Generally, samples containing the Quillaja saponin exhibited lower cohesiveness values (0.17-0.15) than the other samples, indicating that they were more crumbly. Springiness values of the control samples and samples containing the Yucca saponin were similar. Quillaja-containing akara was slightly less springy (0.59 and 0.58 mm) than the other samples. Springiness is the rate at which a deformed material goes back to its undeformed condition after the deforming force is removed (Civille & Szczesniak, 1973). It is an indication of how 'elastic' the product is. The results show that the Quillaja-containing samples were slightly less 'elastic' than the other samples. Chewiness is the energy required to masticate a solid food to a state ready for swallowing (Civille & Szczesniak, 1973). If a product is less 'elastic', it will most likely be less chewy. The results show that the Quillaja-containing samples were the least chewy (0.79 N.mm for 1.5 min whip time and 0.63 N.mm for 3 min whip time). The control samples were the most chewy (1.18-1.42 N.mm), followed by the Yucca-containing samples (1.09-0.94 N.mm).

Instrumental color

Akara prepared with saponins was significantly darker (L*=38.25-39.98) than that produced without saponins (L*=53.44-53.69) as shown in Table 3.3. Also, those made with saponins were more red (a*=16.33-16.92) and less yellow (b*=24.90-28.28) than that made without saponins (a*=14.94-15.10 and b*=34.98-35.24, respectively). Chroma indicates how saturated or intense the color is; akara without saponins showed more saturated color (38.18-38.35) than that made with saponins (29.85-32.99).

For akara, hue angles between 40^{o} and 75^{o} represent brown colors with a lower hue angle indicating more brown color than a higher angle (McWatters *et al.*, 2001). Samples containing saponins had lower hue angles (56.39-59.08^{o}) and were visibly browner than samples which had no saponins (66.63^{o} and 67.98^{o}). Compared with the results obtained by

Table 3.3
Effect of saponin and whipping time on the color of akara[1]

Sample[2]	L* ±SD	a* ±SD	b* ±SD	Hue Angle (°) ±SD	Chroma ±SD	ΔE ±SD
C + 1.5 WH	53.69±4.07 [a]	14.94±2.01 [b]	35.24±1.75 [a]	67.98±1.19 [a]	38.35±3.26 [a]	17.41±3.60 [c]
C + 3 WH	53.44±3.50 [a]	15.10±2.08 [b]	34.98±1.67 [a]	66.63±1.26 [a]	38.18±2.80 [a]	17.41±3.59 [c]
Ys + 1.5 WH	39.98±2.52 [b]	16.92±1.19 [a]	28.28±1.46 [b]	59.08±1.28 [b]	32.99±2.60 [b]	30.18±2.43 [b]
Ys + 3 WH	38.56±2.64 [b]	16.73±1.06 [a]	27.07±1.99 [c]	58.22±1.93 [bc]	31.83±2.86 [c]	31.76±2.12 [ab]
Qs + 1.5 WH	39.39±7.02[b]	16.88±1.60 [a]	26.43±3.85 [c]	57.05±3.19 [cd]	31.47±7.39 [c]	31.17±4.97 [ab]
Qs + 3 WH	38.25±6.81 [b]	16.33±1.37 [a]	24.90±3.74 [d]	56.39±3.26 [d]	29.85±7.29 [d]	32.57±4.44 [a]

[1]Mean values in a column not followed by the same letter were significantly different (α=0.05).
[2]Qs= paste with Quillaja saponin, Ys= paste with Yucca saponin, C= control and WH is whipping time in minutes. L*=lightness (0=black, 100=white), a* = redness, b*=yellowness. Chroma = $(a^{*2} + b^{*2})^{1/2}$, Hue angle = $\tan^{-1}(b^*/a^*)$, $\Delta E = [(L^* - L^*_{reference})^2 + (a^* - a^*_{reference})^2 + (b^* - b^*_{reference})^2]^{1/2}$

Park *et al*. (2004), akara produced from non-decorticated cream cowpeas using the same level of saponin was darker (lower L) and browner (lower hue angles) than akara produced from decorticated black-eyed cowpeas. Visual observation of the flour produced by these two types of cowpeas confirmed that the flour produced by the non-decorticated cream cowpeas was darker, hence this may account for its production of darker akara. This may also be due to the presence of seed coat in the non-decorticated cream cowpeas, which is largely comprised of cellulose. Cellulose may be less able to retain water than starch and other polymers, thus dry out and begin to char in the hot oil.

Total color difference (ΔE) represents the total color change due to treatment (McWatters *et al.*, 2001). Akara made with the saponins had a greater change in color (30.18-32.57) than that made without saponins (17.41). This shows that the addition of saponins to cowpea paste had a significant effect on the overall color of the end product.

Weight, number, and proximate composition of akara

Table 3.4 shows that a higher foaming capacity of the paste resulted in a higher number of akara balls produced per batch and a lower weight of each akara ball. The samples containing saponins produced more akara balls per 100 g batch of cowpea flour (13-16) than the control (11-12). Corresponding values for the weight of the balls showed that akara balls with saponins weighed less (15.3-18.0 g) than that without saponins (19.5-20.4 g). A longer whip time (3 min) produced more akara balls with lower weight than a shorter whip time (1.5 min).

Proximate composition of the akara samples is shown in Table 3.4. The moisture content of samples containing the saponins was significantly lower than the control (49.4% for 1.5 min whip time and 48.1% for 3 min whip time). Quillaja-containing samples had lower moisture content (36.4% for 1.5 min whip and 31.5% for 3 min whip time) than samples containing the Yucca saponin (44.5% for 1.5 min whip time and 41.3% for 3 min whip time). The same volume of each sample was fried; however, the cowpea pastes containing the

Table 3.4
Weight, number, and proximate composition of akara[1]

Sample[2]	Wt. of ball (g) ±SD	Akara balls/100g flour ±SD	Moisture (%) ±SD	Fat (%) ±SD	Protein (%) ±SD	Ash (%) ±SD	Carbohydrates (%) ±SD
C + 1.5 WH	20.36±0.28 [a]	11±0 [d]	49.40±0.46 [e]	18.81±0.28 [f]	19.25±0.12 [a]	5.75±0.01 [a]	56.19±0.18 [a]
C + 3 WH	19.53±0.47 [b]	12±0 [e]	48.10±0.05 [f]	19.65±0.22 [e]	19.26±0.13 [a]	5.60±0.03 [b]	55.49±0.32 [a]
Ys + 1.5 WH	16.91±0.60 [d]	14±0 [b]	44.48±0.30 [c]	25.13±0.39 [d]	17.33±0.99 [b]	5.22±0.03 [c]	52.31±1.36 [b]
Ys + 3 WH	15.31±0.23 [f]	16±1 [a]	41.29±0.45 [d]	28.89±0.23 [c]	16.18±0.20 [c]	4.95±0.04 [d]	49.98±0.39 [c]
Qs + 1.5 WH	18.01±0.69 [c]	13±0 [c]	36.40±0.14 [a]	37.45±0.18 [b]	14.80±0.04 [d]	4.31±0.04 [e]	43.44±0.18 [d]
Qs + 3 WH	16.05±0.81 [e]	15±0 [b]	31.47±0.33 [b]	42.03±0.30 [a]	13.71±0.80 [e]	4.01±0.04 [f]	40.25±1.05 [e]

[1]Mean values in a column not followed by the same letter were significantly different (α=0.05).
[2]Qs= paste with Quillaja saponin, Ys= paste with Yucca saponin, C= control and WH is whipping time in minutes. Fat, protein and ash content are expressed on moisture-free basis; carbohydrate content was determined as 100%- (ash + fat + protein).

saponin contained more air due to an increase in foaming capacity. As a result, the lower moisture content of these samples may be due to the fact that the saponin-containing pastes contained more air per volume than the control, hence less moisture. During frying, the moisture in the product evaporates and is replaced by oil. Increased foaming capacity of the paste which led to more air being incorporated into the paste may have resulted in higher moisture loss than in the control. This is confirmed by the results obtained for the different whip times. Moisture content of the control decreased from 49.4% for 1.5 min whip time to 48.1% for 3 min whip time. Thus it can be concluded that increased porosity of the product played a significant role in increased loss of moisture from the product.

The protein content was significantly different for all samples. The control samples at 1.5 and 3 min whip time had the highest protein content (19.25% and 19.26%, respectively) compared to the saponin-containing samples. At the same whip time, the protein content for Yucca-containing samples was higher (17.33% for 1.5 min whip time) than the Quillaja containing samples (14.80% for 1.5 min whip time). In general, a higher whip time resulted in a lower protein content compared to the lower whip time for all samples. This could be due to the fact that the increase in foaming capacity of the saponin-containing samples resulted in akara that contained more fat compared to the control, due to incorporation of more air. Consequently, there was a significant decrease in the ash content of the saponin-containing samples compared with the control. Yucca-containing samples had higher ash content (e.g. 5.22% at 1.5 min whip time) than Quillaja containing samples (e.g. 4.31% at 1.5 min whip time) at the same whip time. The crude fat content of saponin-containing samples was higher (25.1%-42.0%) compared to the control (18.8-19.6%). Quillaja-containing samples had the highest fat content (37.4- 42.0%). This is due to the increased foaming capacity of the paste effected by the addition of the saponins. The fried product became more porous leading to greater moisture loss (as discussed earlier), hence greater oil absorption during frying. According to Saguy & Dina (2003), frying is a dehydration process. As water turns into steam during frying, the formation of pores due to water evaporation allows oil to penetrate into the voids created. The carbohydrate content was calculated by difference, hence the proportionally lower carbohydrate values with increased fat content.

Research has shown that the crust of fried samples contains more oil than the core. Using calorimetry, Aguilera & Gloria (1997) showed that in fried potatoes, the crust contains almost 6 times as much oil as the inner part. Pictures of cut akara samples, as shown in Figs. 3.9 and 3.10, show a ring of oil just beneath the crust of the samples containing Quillaja saponin. According to Mellema (2003), oil can only penetrate where water has evaporated and oil penetration only occurs where the temperature has been sufficiently high, *i.e*. in the crust. Samples containing the Quillaja saponin show a more defined ring of oil at the crust because the bubbles produced by this saponin are larger than those from Yucca saponin; thus with a sufficiently high temperature at the crust, more moisture is evaporated, hence more oil is absorbed.

CONCLUSIONS

The results of this study show that saponins can be effectively used to modify the texture of akara produced from non-decorticated cream cowpeas. Yucca saponin gave more favorable results than the Quillaja saponin due to its higher reduction in the specific gravity of whipped cowpea paste. Though addition of the saponins resulted in an increased fat content of akara, those containing the Yucca saponin had less fat than those with the Quillaja saponin. The textural characteristics of the samples obtained from the two saponins were comparable, however, due to the fact that the Quillaja saponin produced larger air bubbles, the product absorbed more frying oil.

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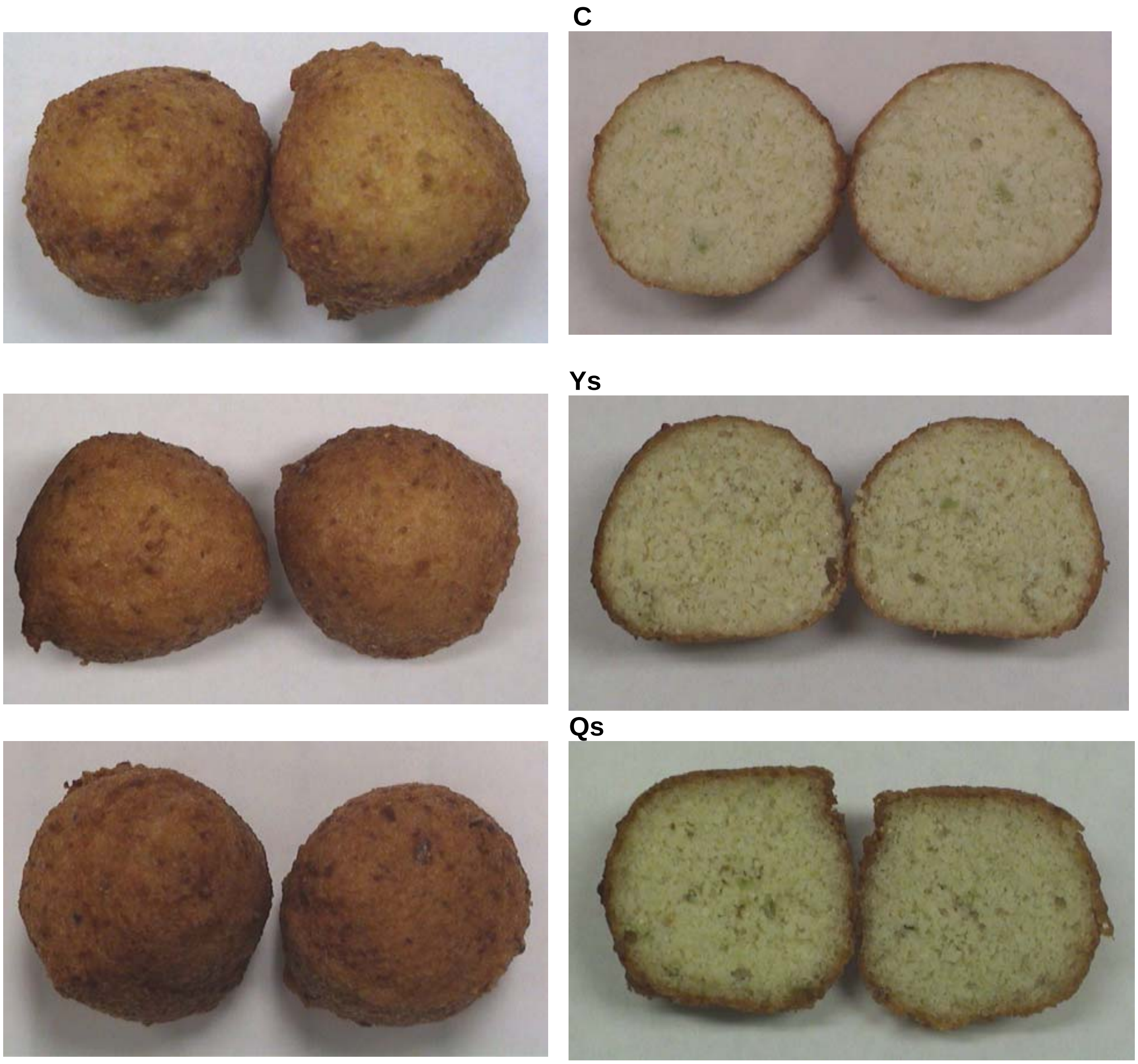

Fig. 3.9. Whole and cut akara samples prepared from pastes whipped for 1.5 min.

C= Control, Ys= akara prepared with 1% Yucca saponin, Qs= akara prepared with 1% Quillaja saponin.

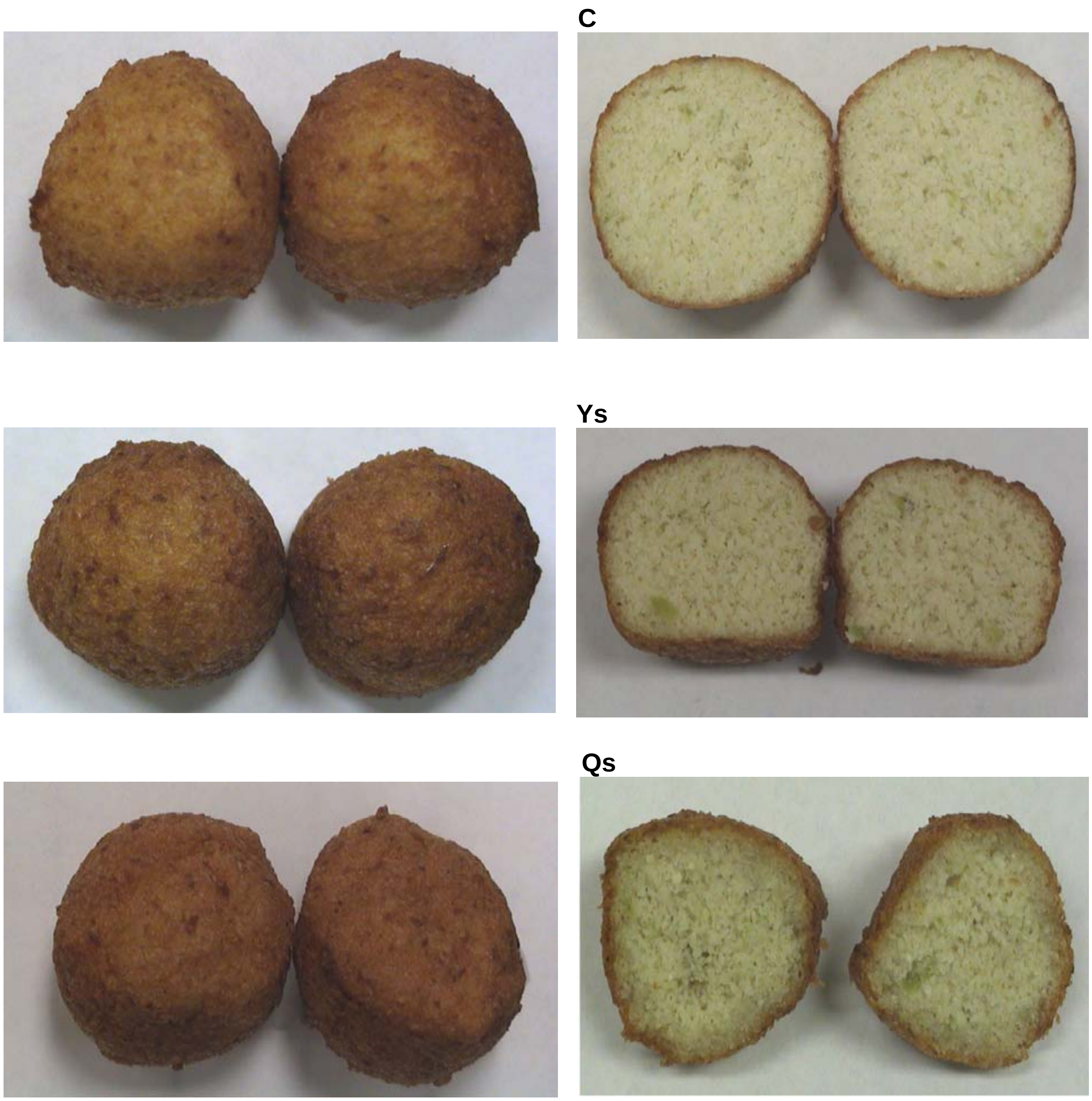

Fig. 3.10. Whole and cut akara samples prepared from pastes whipped for 3 min.

C= Control, Ys= akara prepared with 1% Yucca saponin, Qs= akara prepared with 1% Quillaja saponin.

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CHAPTER 4

IMPROVING THE NUTRITIONAL QUALITY AND MAINTAINING CONSUMPTION QUALITY OF AKARA USING CURDLAN AND COMPOSITE FLOUR[1]

[1]M. A. Plahar, Y.-C. Hung, and K. H. McWatters. Submitted to Journal of Food Science

ABSTRACT

Akara is a novel food product made from seasoned, fried cowpea paste; however, its fat content can be as high as 20-25%. Soybean flour and curdlan were incorporated into cowpea flour to determine their effect on lowering the fat content and on the physical properties of akara. Soybean had a positive effect on lowering the fat content and improving the protein content of akara. At 20% substitution, soybean flour lowered the fat content of akara by 15% and increased the protein content by 30% without significantly affecting the firmness or the color of akara. Curdlan was also effective in lowering the fat content of akara; addition of 1% curdlan decreased the fat content by 30%. However, addition of curdlan significantly increased the firmness of akara and produced a darker-colored product. The paste moisture content of akara containing 20% soybean flour and 1% curdlan was modified to obtain product characteristics comparable to the control (100% cowpea flour) while maintaining a lower fat content. Increasing the moisture content of the paste resulted in an increase in the foaming property and consequently an increase in the oil absorption. Optimum results were obtained for paste with 63% moisture content. Firmness of the product was similar to the control and the fat content was lower (17%) compared to the control (26%).

Key words: akara, cowpea, soybeans, curdlan, fat content

INTRODUCTION

Industries, restaurants, and consumers utilize frying as an important method of food preparation. Deep-fat frying is a convenient method of food preparation; while it has accelerated U.S. acceptance of ethnic foods, bolder flavors, and added a crunch to traditional meals (Sloan, 2000), it has also resulted in the increase of obesity, heart-related diseases as well as some cancers.

Deep-fat frying is defined as the process of cooking foods by immersing them in an edible oil or fat which is at a temperature above the boiling point of water, typically 150-200^{o}C (Farkas and others 1996). Research has shown that the moisture content of the food plays an important role during frying. A review by Mehta and Swinburn (2001), on the factors affecting fat absorption in hot potato chips, showed that voids left by the removal of water through the pores of the chips during frying were filled with cooking fat, especially in the outer layer. Gamble and others (1987) also reported a correlation of 0.998 between oil content and moisture content of potato chips. Moreira and others (1997) reported that the initial moisture content of tortilla chips significantly affected the final oil content of the chips. As initial moisture content increased, the final oil content increased. According to Varela (1988), oil absorption occurs as moisture is removed from the food during frying. As such, preventing the removal of water from a product during deep-fat frying could reduce the oil absorption.

Many snacks and dishes all over the world use fried batter as a constituent, where fried batter is defined as a flour-water mixture which is deep-fried in hot oil. Frying batters are used to add value to a product by improving texture, flavor, weight, and volume (Mohamed and others 1998). A fried cowpea batter product popular in West Africa is akara. The batter is made with imbibed dry seeds or cowpea flour and water, seasoned with bell or hot peppers, onions, and salt and deep-fat fried at 193^{o}C. Research has shown that akara contains about 20-25% fat, most of which is located in the crust of the product. Saguy and Pinthus (1995) reported that product porosity is a significant factor affecting oil uptake in deep-fat frying.

Sales in fast foods, which are mainly fried foods is on the increase. According to Saguy and Dana (2002), Americans spent $6 billion on fast foods in 1970 and the figure grew in 2000 to $110 billion. The consumer's preference for low-fat and fat-free products has been the driving force of the snack food industry to produce reduced-fat products that still retain the desirable texture and flavor (Garayo and Moreira 2002). Research has identified several methods of lowering the oil content of foods such as the use of vacuum frying (Garayo and Moreira 2002), edible films (Williams and Mittal 1999) and modifiers (Patterson 2002a; Falade and others 2003).

Soybean is an important source of high quality but inexpensive protein and oil. With an average protein content of 40% (of total dry matter) and oil content of 20%, soybean has the highest protein content of all food crops, and is second only to groundnut in terms of oil content among food legumes (IITA 2004). Soybean is cheaper compared to other protein-rich foods such as meat, fish, and eggs. Based on human requirements, the essential amino acids are equal to or exceed levels found in egg protein except for the sulfur-containing amino acids. Studies have shown that addition of soybean flour to fried food formulations plays a role in reducing the oil uptake of the product during frying or on the overall fat content. Significant reductions in oil absorption with incorporation of soybean flour have been achieved for various food products (Johnson 1970; Wolf and Cowan 1971; Martin and Davis 1986; Mohamed and others 1995; Huse 1996). Studies done by Wolf and Cowan (1971) and Mohamed and others (1995) hypothesized that the decrease in oil absorption may be related to the rate of denaturation of the protein, and that the denatured proteins form a fat-resistant barrier.

Curdlan is a water-insoluble polysaccharide (β-1, 3 glucan) (Fig 2.3) produced by *Alcaligenes faecalis* var. *myxogenes*, and has a specific character to make an irreversible gel by heating of a water suspension (Harada and others 1966). Curdlan is used as a formulation aid, processing aid, stabilizer, and thickener or texturizer for use in food and was approved for these uses by the U.S. Food and Drug Administration (FDA) in December 1996 (FDA 1996). Approval of curdlan was based on the fact that it consisted of a glucose polymer and a small amount of inorganic salts, mainly sodium chloride; it is non-toxic and the producing organism is also non-pathogenic and non-toxicogenic; and there is a history of safe consumption of similar glucose polymers in food (Spicer and others 1999).

Unlike other gelling agents such as carrageenan, agar-agar, HM pectin, gellan and gelatin gel which gel after heating, then cooling, curdlan gels on heating alone (Deis 1997). Depending on the temperature, it forms two types of heat-induced gel: low-set and high-set. The low-set gel is thermo-reversible and is obtained when an aqueous dispersion is heated to between 55 and 60^{o}C and then cooled to 40^{o}C; the high-set gel is thermo-irreversible, stable at low and high temperatures, and obtained when the aqueous dispersion is heated to above 80^{o}C (Harada and others 1987). According to Funami and others (1999), the thermal gelling properties of curdlan can be considered as a potential oil barrier-forming ingredient for fried foods. In their research on using curdlan to reduce the oil uptake of doughnuts during deep-fat frying, addition of 0.1-0.5% curdlan significantly decreased the final lipid content and oil uptake of doughnuts. It also significantly increased the final moisture content and decreased moisture loss. Curdlan also reduced the breaking stress of the doughnuts by 0.5% compared with sodium carboxy methylcellulose (CMC) and methylcellulose (MC) which increased it.

More often than not, food preferences by human beings are based not on nutritional quality but on such sensory attributes of the food as appearance, color, flavor, texture, and mouthfeel (Damodaran 1996). The production of akara with a desirable texture depends on the foaming ability of its primary ingredient-- cowpea paste. The foaming ability of cowpea paste depends on particle size, hydration time, protein content, and protein solubility. The high protein content (~24%) of cowpea contributes to its foaming capacity (Bressani 1985); the capacity of cowpea proteins to absorb water, to form a foamy structure when whipped, and to produce paste with an appropriate viscosity are important functional characteristics that affect the behavior of cowpea paste in akara production (Phillips and McWatters 1991).

Several important functional properties of proteins (solubility, wettability, dispersibility, thickening, foaming, emulsification, and gelling properties) are affected by the extent of interaction with solvent water. The solvation and dissolution characteristics of proteins affect these properties (Kinsella and Damodaran 1981).

The challenge encountered in altering the composition of products especially to improve the nutritional quality deals with maintaining the quality and sensory acceptability of the reformulated products. Most people would like to eat a healthier diet without fundamentally changing their eating patterns. The unwillingness of the consumer to change dietary habits suggests that there is a great market potential for foods with altered nutritional characteristics but unchanged sensory attributes (Becker and Kyle 1988). Preliminary research conducted to reduce the oil absorption of akara by incorporating soy flour and curdlan in the formulation showed that these additives absorbed moisture when added to the formulation. As a result, the moisture was unavailable to the cowpea flour proteins and also for the formation of bubbles in the paste, resulting in poor hydration characteristics of the paste and hence decreased foaming capacity. The pastes obtained from these formulations were more viscous than the control and the akara balls produced were heavier, denser, and firmer.

The objectives of this study were to:

1. Evaluate the effect of soybean flour and curdlan on the fat content of akara and determine their effect on the physical properties and proximate composition of the product
2. Modify the moisture content of paste containing soy flour and curdlan to obtain product characteristics similar to the control while maintaining improved nutritional quality (lower fat content)

MATERIALS AND METHODS

Cowpea flour production

Dry cowpea seeds (breeding line UCR 97-15-33) were obtained from Inland Empire Foods, Inc. (Riverside, California) and stored at 2°C until used. These cream-type seeds were milled into flour without decortication using a hammer mill (Champion, Model no. 6X14, Champion Products Inc., Eden Prairie, Minnesota) equipped with a 2.54 mm screen.

Soybean flour and curdlan

Partially defatted soybean flour was provided by American Soy and Tofu Corporation, Macon, Georgia. Curdlan was obtained from Sigma-Aldrich Corporation, St. Louis, Missouri, and was stored at 2°C until used.

Preparation of cowpea paste and akara

Cowpea paste was prepared by adding sufficient water to a cowpea-soy flour mixture or cowpea flour-curdlan mixture to obtain a final paste moisture content of 61%. Paste containing soy flour was prepared by substituting 0, 5, 10, 15 and 20% soy flour for cowpea flour and adding the appropriate amount of water. These levels of soy flour were chosen based on previous research by Huse (1996) where a 26% fat content reduction was obtained for up to 6% level of incorporation of soy flour. Paste containing curdlan was prepared by adding 0%, 0.3%, 0.5%, 0.7% and 1% (based on 230g of cowpea paste) to 100g of cowpea flour and adding the appropriate amount of water. These levels of curdlan were chosen based on a previous research by Funami and others (1999) on reducing oil uptake in doughnuts. The mixture was then stirred gently with a rubber spatula and allowed to stand for 15 min. The resulting paste was whipped for 1.5 min in a household mixer (Model 2366, Sunbeam Corp., Delray Beach, Florida) at speed 12 (high). During whipping, a rubber spatula was used to continuously scrap off the paste that adhered to the sides of the mixing bowl to ensure effective mixing. Pastes not containing salt, pepper, and onion were used for physical property evaluations.

After whipping, 9.5% chopped bell peppers, 9.5% chopped onions, and 1.5% salt was manually folded into the paste with a rubber spatula. A #40 ice cream scoop (~20 ml) was used to dispense the paste into hot (193°C) peanut oil in an atmospheric fryer (Kitchen Kettle™ electric multi-cooker, National Presto Industries, Eau Claire, Wisconsin). After 3 min frying (1.5 min on each side) akara balls were drained on absorbent paper towels, cooled to room temperature, counted, weighed (5 samples per batch), and used for texture and color measurements.

Effect of moisture content of composite flour paste on akara quality

Preliminary studies conducted to determine the effect of soybean and curdlan showed that incorporating these modifiers into cowpea flour decreased the foaming capacity of the paste. Composite flour containing both curdlan and soybean flour at a level that resulted in the greatest decrease in fat content and greatest increase in protein content of akara from the first part of the study was identified. This mixture was used for the study on moisture content, following the same steps as described above except the moisture content of the composite flour mixture was adjusted to achieve 61%, 63% and 65% paste moisture content. Akara was prepared as described above.

Apparent viscosity and specific gravity measurements

The apparent viscosity of whipped pastes was determined at 23°C using a digital viscometer (Model HATD, Brookfield Engineering Laboratories, Inc., Stoughton, Massachusetts) equipped with a T spindle [number C, cross bar length of 1.064 in (27.1 mm)] at 10 rpm. Whipped cowpea paste (250 ml) was poured into a 600 ml beaker and tapped 10 times on the heel of the palm to remove any air pockets. An inbuilt leveler was used to level the instrument. Readings were recorded continuously by an attached recorder for the same sample as the spindle was immersed to a depth of 2.5 cm and returned to the surface (total distance = 5 cm). The readings were read off a graph and the average taken. The apparent viscosity (Pa.s) was calculated by the following formula:

Viscosity in Pa.s = spindle factor x viscometer reading x 10^{-3}

Spindle factor = 20 M/rpm

M = 1000, rpm = 10

Specific gravity of unwhipped and whipped pastes was determined in triplicate according to the modified method of Kethireddipalli and others (2002).

Instrumental color measurement

Five akara balls were randomly selected from each batch; the Hunter color values (L*, a*, b*) of the exterior surface were measured using a Minolta colorimeter (Model CR-200, Osaka, Japan) calibrated with a brown reference tile (L* = 69.82, a* = 19.17 and b* = 31.75). Each ball was measured twice, one on either side. Hue angle was calculated as $\tan^{-1}(b^*/a^*)$, chroma as $(a^{*2}+b^{*2})^{½}$ and total color difference (ΔE) as $[(L^*-L^*reference)^2 + (a^*-a^*reference)^2 + (b^*-b^*reference)^2]^{½}$.

Instrumental texture measurement

An Instron universal testing machine (Model 5544, Instron, Inc., Canton, Massachusetts) fitted with a 2000 N load cell was used to determine the texture of akara balls. The same akara balls used for the color measurements were used. A cube of 1 cm was cut from the crumb portion of the akara ball and compressed twice in reciprocating motion each time to 25% of its original height at a crosshead speed of 50 mm/min (Kethireddipalli and others 2002). Peak heights were measured and the force required to shear was reported as Newtons (N). Firmness, cohesiveness, chewiness, and springiness were calculated from the force-deformation curve as follows: Firmness= maximum force from the first compression (Newtons); Cohesiveness= the strength of the internal bonds making up the body of the product (ratio of positive force areas under first and second compressions); Springiness= distance over which the sample recovers its height between the end of the first compression and the start of the second compression; and Chewiness= firmness x cohesiveness x springiness (Szczesniak 2002).

Proximate analysis

The moisture content of akara samples was determined by grinding and vacuum drying at 70°C for 24 h [American Association of Cereal Chemists (AACC) 1976 Method 44-40]. The fat content was determined by extraction with petroleum ether for 24 h in a Goldfisch apparatus (Labconco, Kansas City, Mo.) (AACC 1976, Method 30-26). Ash content was determined by using the moisture-free and fat-free samples (AACC 1976 Method 08-01). Protein content was determined by the nitrogen combustion method (LECO, FP-2000, Warrendale, Penn.), using moisture-free and fat-free samples. A factor of 6.25 for cowpea and 5.71 for soybean was used to convert nitrogen to protein content [Food and Agriculture Organization of the United Nations (FAO) 1970]. The carbohydrate content was determined by subtracting the sum of ash, fat, and protein content from 100%.

Statistical analysis

All data were analyzed using analysis of variance (ANOVA) procedures from the Statistical Analysis System (SAS). Mean comparisons were performed using Duncan's Multiple Range Test (SAS 2000).

RESULTS AND DISCUSSION

Specific gravity and apparent viscosity measurements

Foaming properties are important to the textural character of akara (Kethireddipalli 1999). Whipping of the paste is essential for formation of foam (Patterson and others 2002b), and it incorporates air into the paste and helps to evenly distribute the air bubbles. Specific gravity measurements of the paste can be used to determine the foaming capacity. The higher the foaming capacity of a paste or mixture, the greater the amount of air incorporated into it during whipping and the lower will be its specific gravity (Campbell and others 1979).

Specific gravity values of soy-substituted cowpea flour pastes (Table 4.1) show that specific gravity of the whipped pastes was significantly affected by the addition of soy flour. The addition of soy flour significantly increased the specific gravity of the pastes after whipping. The

Table 4.1
Effect of defatted soy flour and curdlan on specific gravity and apparent viscosity of cowpea paste[1]

Sample[2]	Specific gravity before whipping ±SD	Specific gravity after whipping ±SD	Reduction in specific gravity (%) ±SD	Apparent viscosity (Pa.s) ±SD
Control	1.05±0.01 ab	0.65±0.01 d	38.17±0.65 a	49.75±2.47 c
95g C + 5g S	1.05±0.01 a	0.66±0.01 c	36.71±1.30 b	52.00±0.00 c
90g C + 10g S	1.04±0.01 ab	0.70±0.01 b	32.84±0.81 c	63.75±1.06 ab
85g C + 15g S	1.04±0.01 b	0.74±0.02 a	29.18±2.50 d	56.50±6.36 bc
80g C + 20g S	1.05±0.01 a	0.74±0.01 a	29.56±1.59 d	74.00±5.66 a
Control	1.05±0.01 a	0.65±0.00 e	38.25±0.85 a	47.50±0.40 e
0.3% Curdlan	1.05±0.01 a	0.68±0.01 d	35.48±0.73 b	67.00±0.70 d
0.5% Curdlan	1.05±0.02 a	0.74±0.00 c	29.20±1.12 c	88.00±2.10 c
0.7% Curdlan	1.04±0.01 a	0.82±0.03 b	21.23±2.44 d	115.50±3.20 b
1.0% Curdlan	1.04±0.02 a	0.86±0.00 a	17.13±2.24 e	148.00±2.10 a

[1]For each added ingredient, mean values in a column not followed by the same letter were significantly different (α=0.05).
[2]C = cowpea flour, S = soy flour

lowest specific gravity after whipping was obtained for the control (0.65) which contained no soy flour and the highest was obtained for samples containing 15% and 20% soy flour (0.74). Soy flour used in the formulation contained twice as much protein (48%) as cowpea flour (24%) thus the formulations containing soy flour will have higher protein content than the control. According to Wolf and Cowan (1971), soy proteins contain numerous polar side chains along their peptide backbones, thus making the protein hydrophilic. As a result, addition of soy proteins such as flours to food products increases water absorption as the proteins absorb water and tend to retain it in finished food products. Aeration of food products produces foams which are defined by Niranjan (1999) as gas bubbles separated by thin films and these thin films are liquid layers. Thus due to increased water absorption of the soy-containing pastes, less liquid was made available for the formation of bubbles to produce a foam, resulting in the reduced foaming capacity of these pastes as the amount of soy flour was increased.

The addition of curdlan to the cowpea flour resulted in a significant increase in the specific gravity of the paste after whipping (Table 4.1). According to Damodaran (1994), the basic requirements for a protein to be a good foaming agent include the ability to rapidly adsorb at the air-water interface during whipping. Curdlan absorbs and retains moisture thus making the moisture unavailable to the proteins of the cowpea flour. Since the proteins were not sufficiently hydrated, poor foaming capacity resulted, which caused a reduction in the specific gravity of the paste. There was an increase in the specific gravity of the pastes after whipping as the amount of curdlan was increased from 0.3% to 1%. The lowest specific gravity was obtained for the control (0.65) and the highest was obtained for the paste with the highest quantity of curdlan (1% curdlan) (0.86).

Increasing the soy content of the paste resulted in a significant increase in the apparent viscosity (Table 4.1) with the control paste having the lowest apparent viscosity (49.75 Pa.s) and paste containing the highest amount of soy flour (20%) having the highest apparent viscosity (74.00 Pa.s.). Apparent viscosity is an indication of resistance to flow. Increasing the amount of air incorporated into the paste due to an increase in foaming capacity will result in pastes with less resistance to flow. As expected, increasing the soy flour content of the paste resulted in decreased foaming capacity, thus, the higher the soy flour content of the paste, the higher the resistance to flow (apparent viscosity).

As shown in Table 4.1, the addition of curdlan to cowpea flour resulted in an increase in the apparent viscosity of the pastes. Increasing the amount of curdlan increased the resistance to flow of the paste resulting in an increase in the apparent viscosity. This is also because curdlan absorbs moisture making it unavailable to the paste, thus making the paste thicker and more resistant to flow. The highest resistance to flow was observed in the paste containing 1% curdlan which had the highest apparent viscosity (148.00 Pa.s) and the lowest resistance to flow was observed in the control paste (47.50 Pa.s).

Texture

The textural quality of the soy-containing akara samples (Table 4.2) was not significantly affected by the addition of soy flour; however curdlan-containing akara showed a significant increase in firmness (Table 4.2). The firmness of akara containing 0.3% and 0.5% curdlan was not significantly different from the control but on addition of 0.7% and 1% curdlan, the firmness of the akara increased (8.29 N and 9.10 N, respectively, compared to 7.21 N for the control). There was no significant change in chewiness or springiness except at the 1% curdlan level where a significant decrease in the springiness of akara (0.53 mm) occurred, compared to the control and the other curdlan-containing akara. Cohesiveness is defined as the extent to which a material can be deformed before it ruptures (physical definition) or the degree to which a substance is compressed between the teeth before it breaks (sensory definition) (Szczesniak 2002). There was a significant decrease in cohesiveness as the amount of curdlan increased with akara containing 1% curdlan being the least cohesive (0.14) and the control being the most cohesive (0.18).

Table 4.2
Effect of defatted soy flour and curdlan on the texture of akara[1]

Sample[2]	Firmness (N)[3] ±SD	Cohesiveness[4] ±SD	Springiness (mm)[5] ±SD	Chewiness (N.mm)[6] ±SD
Control	7.63±0.76 [a]	0.18±0.01 [a]	0.56±0.02 [b]	0.76±0.10 [a]
95g C + 5g S	7.79±0.80 [a]	0.19±0.01 [a]	0.58±0.01 [ab]	0.84±0.10 [a]
90g C + 10g S	7.72±1.01 [a]	0.18±0.02 [a]	0.57±0.02 [ab]	0.79±0.16 [a]
85g C + 15g S	7.32±1.85 [a]	0.18±0.01 [a]	0.57±0.02 [ab]	0.76±0.20 [a]
80g C + 20g S	6.83±1.24 [a]	0.19±0.02 [a]	0.58±0.02 [a]	0.75±0.18 [a]
Control	7.21±0.77 [c]	0.18±0.02 [a]	0.56±0.02 [a]	0.71±0.07 [a]
0.3% Curdlan	7.75±1.14 [bc]	0.16±0.01 [b]	0.55±0.03 [a]	0.69±0.08 [a]
0.5% Curdlan	7.75±0.87 [bc]	0.16±0.01 [bc]	0.55±0.02 [a]	0.68±0.09 [a]
0.7% Curdlan	8.29±1.01 [b]	0.15±0.01 [cd]	0.55±0.02 [a]	0.68±0.08 [a]
1.0% Curdlan	9.10±1.43 [a]	0.14±0.01 [d]	0.53±0.02 [b]	0.69±0.11 [a]

[1]For each added ingredient, mean values in a column not followed by the same letter were significantly different (α=0.05)
[2]C = cowpea flour, S = soy flour
[3]Firmness= force necessary to attain a given deformation (Newtons)
[4]Cohesiveness= the strength of the internal bonds making up the body of the product (ratio of positive force areas under first and second compressions)
[5]Springiness= distance over which the sample recovers its height between the end of the first bite and the start of the second bite.
[6]Chewiness= firmness x cohesiveness x springiness

Instrumental color

The Hunter system of color measurements defines L* as the darkness of a product with L*=100 as white and L*=0 as black. It also defines a* as the redness and b* as the yellowness of a product. Table 4.3 shows the color measurements of the soy-containing samples. There was no significant change in the darkness of akara containing soy flour for all samples except at the 15% soy flour level where a slight darkening of the color (L*=59.47) occurred. There was also no significant change in the redness or yellowness of the soy-containing samples except at the 20% soy flour level where decreased redness and yellowness were observed. As a result, the total color change (ΔE) due to treatment was not significantly different for all of the samples except for akara containing 15% soy (ΔE=13.47). According to McWatters and others (2001), for akara, hue angles between 40^{o} and 75^{o} represent brown colors with a lower hue angle indicating more brown color than a higher hue angle. Results show that there was no significant change in the hue angles of the soy-containing akara except at the15% soy flour level where more brown color (hue angle =71.52) developed. Chroma indicates how saturated or intense a color is; the results show that color saturation for all of the samples was not significantly different except for akara containing 20% soy flour which exhibited lower color saturation (33.06). This could be due to the fact that this sample was less yellow (lower b*) and less red (lower a*) than the rest of the samples.

The results show that increasing the amount of curdlan resulted in a significant increase in the darkness (lower L*) of the akara. The control samples were lighter (L*=62.63) than akara containing curdlan, with akara containing 1% curdlan having the darkest color (L*=55.69). Curdlan remains colorless after heating; therefore, the change in color of akara could be due to the fact that curdlan absorbed moisture from the paste, thus the lower water activity may have favored an increase in the Maillard reaction, causing the crust of the akara to brown faster. Addition of curdlan also increased the redness (higher a*) and yellowness (higher b*) of the

Table 4.3
Effect of defatted soy flour and curdlan on the color of akara[1]

Sample[2]	L* ±SD	a* ±SD	b* ±SD	Hue Angle (°) ±SD	Chroma ±SD	ΔE ±SD
Control	62.30±2.63 [a]	9.90±1.76 [bc]	33.64±2.16 [a]	73.68±2.24 [a]	35.09±2.43 [a]	12.03±1.21 [b]
95g C + 5g S	61.48±3.02 [a]	10.49±2.17 [ab]	33.94±2.07 [a]	72.95±2.61 [a]	35.56±2.51 [a]	12.23±1.39 [b]
90g C + 10g S	61.68±2.89 [a]	10.42±2.13 [ab]	33.88±2.63 [a]	73.05±2.27 [a]	35.47±3.08 [a]	12.26±0.91 [b]
85g C + 15g S	59.47±4.62 [b]	11.39±2.88 [a]	33.68±2.41 [a]	71.52±3.74 [b]	35.65±2.99 [a]	13.47±2.25 [a]
80g C + 20g S	62.91±2.89 [a]	9.07±1.59 [c]	31.77±2.17 [b]	74.13±1.96 [a]	33.06±2.43 [b]	12.27±1.32 [b]
Control	62.63±2.84 [a]	9.25±1.71 [c]	32.75±1.78 [c]	74.31±2.36 [a]	34.05±2.04 [c]	12.25±1.19 [c]
0.3% Curdlan	58.87±3.28 [b]	12.00±2.02 [b]	35.42±0.93 [ab]	71.35±2.68 [b]	37.44±1.38 [b]	13.27±1.77 [bc]
0.5% Curdlan	57.68±3.96 [bc]	13.08±2.24 [ab]	35.25±1.47 [ab]	69.74±2.83 [c]	37.65±1.93 [b]	13.75±2.54 [b]
0.7% Curdlan	57.31±3.96 [bc]	13.73±2.43 [a]	35.97±1.11 [a]	69.20±3.24 [c]	38.57±1.58 [a]	14.00±2.49 [ab]
1.0% Curdlan	55.69±4.55 [c]	13.78±2.55 [a]	34.74±1.59 [b]	68.42±3.85 [c]	37.45±1.69 [b]	15.15±3.14 [a]

[1]For each added ingredient, mean values in a column not followed by the same letter were significantly different (α=0.05).
[2]C = cowpea flour, S = soy flour. L*=lightness (0=black, 100=white), a* = redness, b*=yellowness. Chroma = $(a^{*2} + b^{*2})^{1/2}$, Hue angle = $\tan^{-1}(b^*/a^*)$, $\Delta E = [(L^*-L^*_{reference})^2 + (a^*-a^*_{reference})^2 + (b^*-b^*_{reference})^2]^{1/2}$

akara, compared to the control. Consequently, hue angles decreased as the amount of curdlan increased. The control had the highest hue angle (74.31) and had less brown color than curdlan-containing akara (68.42-71.35). Akara containing 0.5%-1% curdlan had similar hue angles, which were lower than that of akara containing 0.3% curdlan. Akara containing curdlan also had more saturated, intense (higher chroma values) than the control. Thus there was a significant change in total color due to addition of curdlan as shown by ΔE values. The control showed the least change (12.25) while akara containing 1% curdlan showed the most color change due to treatment (15.15).

Weight, number and proximate composition of akara

The lower the foaming capacity of the paste containing soy flour, the higher the weight of the finished product (Table 4.4). Increasing the amount of soy flour in the sample resulted in a significant increased weight of akara with the control weighing the least (17.57 g) and the samples containing 15% and 20% soy weighing the most (19.83, 19.91 g, respectively). This is because of the decreased foaming capacity of the pastes resulting in more solids per volume and less air incorporated as the concentration of soy flour increased. Thus there was a corresponding decrease in the number of balls obtained per batch (100 g composite flour).

Increasing the amount of curdlan added to cowpea flour resulted in a progressively significant increase in the weight of akara obtained (Table 4.4). This is due to absorption of moisture by the curdlan, resulting in poorer foaming capacity of the paste. There was also a decrease in the number of akara balls obtained per 100 g batch of cowpea flour compared to the control.

Table 4.4 also shows the proximate composition of the soy-containing samples. There was a significant decrease in the fat content of the samples with the control exhibiting the highest fat content (26.30%). With the addition of 5% soy flour, the fat content decreased to 23.23%, then to 22.38% and 22.69% for samples containing 10% and 15% soy flour, respectively. Addition of 20% soy flour then resulted in a slight increase in the fat content to

Table 4.4
Effect of defatted soy flour and curdlan on the weight, number and proximate composition of akara[1]

Sample[2]	Wt. of ball (g) ±SD	Akara balls/100g flour ±SD	Moisture (%) ±SD	Fat (%) ±SD	Protein (%) ±SD	Ash (%) ±SD	Carbohydrates (%) ±SD
Control	17.57±0.48 c	14±0 a	51.75±0.17 a	26.30±0.29 a	16.68±0.59 c	4.89±0.23 b	52.13±0.96 ab
95g C + 5g S	18.09±0.63 c	14±0 a	52.10±1.67 a	23.23±0.09 b	18.80±0.47 bc	5.25±0.19 a	52.72±0.59 a
90g C + 10g S	19.05±0.75 b	13±0 a	52.62±1.30 a	22.38±0.31 c	19.27±1.57 b	5.38±0.05 a	52.97±1.65 a
85g C + 15g S	19.83±0.88 a	13±0 b	53.26±0.05 a	22.69±0.44 c	21.21±1.40 a	5.36±0.13 a	50.74±1.08 bc
80g C + 20g S	19.91±0.94 a	13±0 b	53.00±1.49 a	23.44±0.10 b	21.72±0.53 a	5.35±0.06 a	49.49±0.55 c
Control	17.57±0.48 c	14±0 a	51.75±0.17 a	24.49±0.08 a	17.07±1.18 a	5.01±0.23 b	53.43±1.03 c
0.3% Curdlan	18.56±0.44 d	13±0 ab	51.85±0.19 c	23.11±0.20 ab	17.32±0.68 a	5.01±0.08 b	54.56±0.66 bc
0.5% Curdlan	19.10±0.71 c	13±0 bc	52.26±0.73 c	21.95±1.58 b	17.21±1.50 a	4.96±0.10 b	55.88±0.51 b
0.7% Curdlan	19.94±0.67 b	13±0 bc	53.46±0.72 b	19.27±1.20 c	17.12±0.59 a	5.14±0.03 a	58.47±1.37 a
1.0% Curdlan	20.89±0.54 a	12±1 c	54.59±0.41 a	17.23±0.40 d	18.65±1.43 a	5.26±0.04 a	58.86±1.79 a

[1]For each added ingredient, mean values in a column not followed by the same letter were significantly different (α=0.05).
[2]C = cowpea flour, S = soy flour. Fat, ash and protein content are expressed on dry-weight basis; carbohydrate content was determined as 100%- (ash + fat + protein).

Increasing the soy flour content of the akara resulted in a significant increase in the protein content (Table 4.4). The control contained the lowest protein content (16.68%) while samples made with 15% and 20% soy flour contained the highest (21.21% and 21.72%, respectively). Substituting cowpea flour with 20% soy flour resulted in a 30% increase in the protein content. Substituting cowpea flour with soy flour to make akara was not only beneficial in lowering the fat content of the product but also in increasing the protein content. Cowpeas and soybeans are low-cost sources of protein; their usage in foods will not only benefit the developing countries where meat and eggs are expensive and sometimes unavailable to the poorer regions but also the developed countries where a low-carbohydrate, high-protein diet has been shown to be healthier.

Meats and produce are a major part of a low-carbohydrate diet which according to a recent article by Golden (2004) can put a strain on pocket books. This is because according to this article, the Food Marketing Institutes 2004 Trends Report states that a one-person household spends on average $59 a week on groceries, but to follow a low-carbohydrate meal plan, that cost jumps to $99.89 for the Atkins Diet and $91.28 for the South Beach Diet. This almost doubles the grocery cost. As a result, the national health interview study shows that 26% of those with income less than $17,000 are overweight compared to 18% for those making over $67,000 per year. So for those on a limited income, a diet consisting of animal proteins causes a financial strain. Supplementing cowpea with soybeans improves the protein content of a product due to the high protein content of both cowpeas and soybeans. In the United States cowpeas are mainly boiled and eaten as-is and soybeans are processed for oil. Akara made from these two legumes will provide a more nutritious and innovative alternative use and encourage increased production of these two legumes in the country.

Table 4.4 shows no significant difference in the protein content of the curdlan-containing akara, compared to the control. This because curdlan is a polysaccharide and does not contain protein. There was a slight increase in the ash content of akara containing 0.7 and 1.0%

curdlan. Addition of curdlan resulted in a significant decrease in the fat content of akara. Addition of 1% curdlan to akara formulation resulted in a 29.6% decrease in the fat content of the product. The control sample had the highest fat content (24.49%) while akara with 1% curdlan had the lowest (17.23%) (Table 4.4). This could be due to the fact that curdlan absorbs moisture and retains it in the structure of the product, thus preventing loss of moisture during frying. As a result, fewer voids are left in the product to be filled by the frying oil. This is confirmed by the results obtained for the moisture content of akara which showed a significant increase with increase in the amount of curdlan added.

Effect of moisture content of composite flour paste on akara quality

The thickening and foaming property of proteins is affected by the extent of interaction with solvent water (Kinsella and Damodaran 1981). Table 4.5 shows the specific gravity and apparent viscosity of cowpea pastes with specified formulations. Increasing the moisture content of the paste resulted in a decrease in the specific gravity after whipping. The reduction in paste specific gravity after whipping is a good measure of foaming capacity (Kethireddipalli and others 2002) because according to Campbell and others (1979) the greater the amount of air incorporated into the paste the lower will be its specific gravity. There was a significant difference in the specific gravity of the pastes either at 61%, 63% or 65% moisture content. The lowest specific gravity after whipping was obtained for the control paste (0.65), followed by the paste with the highest moisture content (65%) with a specific gravity of 0.77. The highest specific gravity (0.97) was obtained for the paste containing 20% soy flour, 1% curdlan, and 61% (lowest) moisture content. Curdlan tends to absorb moisture so less moisture is available to hydrate the soy and cowpea proteins. Soy flour has twice as much protein (48%) as cowpea flour and these proteins are hydrophilic. An increase in the protein content thus led to an increase in the absorption of moisture and due to the increase in water absorption, less moisture was made available for the formation of bubbles to make foam. Thus, increasing the moisture content of the paste led to an increase in its foaming capacity.

Table 4.5
Effect of increasing paste moisture content on specific gravity and apparent viscosity of cowpea paste containing 20% soy flour and 1% curdlan[1]

Sample	Specific gravity before whipping ±SD	Specific gravity after whipping ±SD	Reduction in specific gravity (%) ±SD	Apparent viscosity (Pa.s) ±SD
Control (61% paste moisture content)	1.05±0.01 [a]	0.65±0.01 [d]	38.17±0.65 [a]	48.3±2.47 [b]
61% paste moisture content	1.05±0.01 [a]	0.97±0.03 [a]	7.42±1.95 [d]	66.00±4.58 [a]
63% paste moisture content	1.03±0.01 [b]	0.85±0.02 [b]	18.07±1.49 [c]	47.17±0.58 [b]
65% paste moisture content	1.03±0.02 [b]	0.77±0.01 [c]	25.10±1.58 [b]	28.67±1.61 [c]

[1]Mean values in a column not followed by the same letter were significantly different (α=0.05).

Increasing the moisture content of the paste also resulted in a corresponding decrease in the apparent viscosity. As more water was made available in the paste due to the increase in moisture content, more bubbles were formed leading to incorporation of air into the paste. Paste with 63% moisture content was similar in apparent viscosity (47.17 Pa.s) to the control (48.30 Pa.s). The lowest apparent viscosity was however obtained for paste with 65% moisture content (28.67 Pa.s).

The textural quality of akara obtained from the cowpea pastes was significantly affected by the change in moisture content. Table 4.6 shows that the firmness of the control was similar (7.63 N) to akara made from pastes with 61% (7.09 N) and 63% (6.87 N) moisture content; however, akara made from paste with 65% moisture content was less firm (6.17 N). Proper hydration of the cowpea proteins in the paste led to an increase in the foaming capacity and a decrease in the apparent viscosity, as shown in Table 4.5. According to McWatters and others (1988), the foaming capacity of paste is significant in determining the textural quality of akara. Cohesiveness and springiness of akara made from paste with 65% moisture content were similar to the control. The control sample was more chewy (0.76 N.mm) than the samples containing soy flour and curdlan. This may be due to the greater strength of internal bonds making up the body of the product.

Akara prepared from the control paste was significantly lighter (higher L*) than akara made from the other pastes (Table 4.7). The hue angles show that akara prepared from the control paste and from paste with 65% moisture content was less brown (73.68 and 73.45^{o}, respectively) than akara prepared from paste with 61% and 63% moisture content. The lower chroma values (lower color saturation) of these products (control and akara prepared from paste with 65% moisture content) can be attributed to their lower a* (less redness) and lower b* (less yellowness) values.

Table 4.6
Effect of increasing paste moisture content on the texture of akara prepared from cowpea paste containing 20% soy flour and 1% curdlan[1]

Sample	Firmness (N)[2] ±SD	Cohesiveness[3] ±SD	Springiness (mm)[4] ±SD	Chewiness (N.mm)[5] ±SD
Control (61% paste moisture content)	7.63±0.76 [a]	0.18±0.01 [a]	0.56±0.02 [a]	0.76±0.10 [a]
61% paste moisture content	7.09±1.41 [a]	0.10±0.02 [c]	0.42±0.04 [c]	0.32±0.11 [c]
63% paste moisture content	6.87±0.80 [ab]	0.15±0.02 [b]	0.49±0.02 [b]	0.53±0.10 [b]
65% paste moisture content	6.17±1.02 [b]	0.17±0.02 [a]	0.54±0.04 [a]	0.58±0.13 [b]

[1]Mean values in a column not followed by the same letter were significantly different (α=0.05)
[2]Firmness= force necessary to attain a given deformation (Newtons)
[3]Cohesiveness= the strength of the internal bonds making up the body of the product (ratio of positive force areas under first and second compressions)
[4]Springiness= distance over which the sample recovers its height between the end of the first bite and the start of the second bite.
[5]Chewiness= firmness x cohesiveness x springiness

Table 4.7
Effect of increasing paste moisture content on the color of akara prepared from cowpea paste containing 20% soy flour and 1% curdlan[1]

Sample	L* ±SD	a* ±SD	b* ±SD	Hue Angle (°) ±SD	Chroma ±SD	ΔE ±SD
Control (61% paste moisture content)	62.30±2.63 a	9.90±1.76 b	33.64±2.16 c	73.68±2.24 a	35.09±2.43 b	12.03±1.21 b
61% paste moisture content	58.99±3.00 bc	13.23±2.12 a	35.78±1.32 a	69.80±2.61 b	38.19±1.82 a	12.66±1.62 ab
63% paste moisture content	57.60±3.74 c	13.14±2.31 a	34.76±1.37 b	69.35±3.38 b	37.22±1.57 a	13.60±2.66 a
65% paste moisture content	60.21±2.61 b	9.59±2.25 b	31.88±2.11 d	73.45±2.87 a	33.33±2.60 c	13.38±1.68 a

[1]Mean values in a column not followed by the same letter were significantly different (α=0.05).
L*=lightness (0=black, 100=white), a* = redness, b*=yellowness, Chroma = $(a^{*2} + b^{*2})^{1/2}$, Hue angle = $\tan^{-1}(b^*/a^*)$, $\Delta E = [(L^* - L^*_{reference})^2 + (a^* - a^*_{reference})^2 + (b^* - b^*_{reference})^2]^{1/2}$

Akara prepared from the control paste weighed less than the rest of the samples (17.57 g) (Table 4.8) due to higher foaming capacity of the paste (Table 4.5) which resulted in a more porous structure. Akara prepared from paste containing 20% soy flour, 1% curdlan, and 61% moisture content weighed more (23.6 g) than the rest of the samples. Increasing the moisture content of the paste resulted in a decrease in the weight of the akara balls as well as an increase in the number of balls obtained from each batch of paste. However, more akara balls (14) were obtained from the control than from the soy/curdlan-supplemented samples, and these weighed less because the control had the highest foaming capacity.

Akara prepared from the control paste had the least moisture content (51.7%) (Table 4.8). The control paste and paste containing 20% soy flour, 1% curdlan, and 61% moisture content were both prepared with enough water to obtain the same initial paste moisture content, but the final moisture content of the cooked product prepared from the control had lower moisture content. This is because the presence of the soy flour and curdlan in the rest of the samples retained moisture in the product during frying. During frying, as the temperature increases, moisture evaporates from the product leaving voids that are filled by the frying fat. Akara from the control paste thus had more fat than the rest of the samples. The fat content of akara increased with increasing moisture content of paste due to an increase in the foaming capacity of the pastes; increasing the foaming capacity of the paste provided a product structure that was open and porous, resulting in greater oil absorption during frying. Akara prepared from pastes containing soy flour and curdlan contained more protein compared with the control due to the presence of the soy flour. Ash values for all samples were similar.

CONCLUSIONS

This study has shown that soybean flour and curdlan were successfully used individually to reduce the fat content of akara. While they each reduced the foaming capacity of the paste, soybean flour did not affect the texture of akara. The addition of soybean flour to the akara formulation had the added benefit of increasing the protein content of the end product. Although

Table 4.8
Effect of increasing paste moisture content on the weight, number and proximate composition of akara prepared from cowpea paste containing 20% soy flour and 1% curdlan[1]

Sample	Wt. of ball (g) ±SD	Akara balls/100g flour ±SD	Moisture (%) ±SD	Fat (%) ±SD	Protein (%) ±SD	Ash (%) ±SD	Carbohydrates (%) ±SD
Control (61% paste moisture content)	17.57±0.48 d	14±0 a	51.75±0.17b	26.30±0.29 a	22.24±0.59 c	6.64±0.23 a	44.82±0.96 b
61% paste moisture content	23.59±0.59 a	10±0 d	55.65±0.79 a	12.82±0.81 d	26.72±0.63 a	6.88±0.72 a	53.58±0.22 a
63% paste moisture content	21.80±0.56 b	12±0 c	56.34±0.49 a	17.06±0.97 c	24.08±1.61 bc	7.66±0.69 a	51.20±2.72 a
65% paste moisture content	20.73±0.60 c	13±0 b	55.74±0.52 a	24.94±0.48 b	25.80±1.41ab	7.21±0.53 a	42.05±1.34 b

[1]Mean values in a column not followed by the same letter were significantly different (α=0.05).
Fat, protein and ash content are expressed on moisture-free basis; carbohydrate content was determined as 100%- (ash + fat + protein)

curdlan reduced oil absorption during frying, it increased the firmness of the end product compared to the control.

Incorporating both soybean flour and curdlan into the akara formulation further decreased oil absorption; however, this resulted in a further decrease in the foaming capacity of the paste and increased firmness of the end product. Proper hydration of cowpea composite paste was essential for producing akara that had similar physical/functional properties to traditionally-made, good-quality akara. Increasing the moisture content of the paste produced pastes with foaming and flow properties comparable to the control as well as less firm end products. However, the best qualities were obtained for paste with 63% moisture content because in addition to having similar flow properties as the control, the firmness of the product was similar, while the fat content (17.06%) was significantly less than the control (26.3%). As a result, proper hydration of the paste resulted in a product with similar physical characteristics as the control but with improved nutritional (fat and protein content) qualities.

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CHAPTER 5

SUMMARY AND CONCLUSIONS

Addition of saponins to cowpea paste and increasing whip time significantly affected the foaming capacity of the paste as well as the physical properties of the end product. The presence of Quillaja and Yucca saponins resulted in an increase in the foaming capacity of the paste and consequently a decrease in the viscosity. Increasing the foaming capacity caused an increase in paste volume due to incorporation of air into the paste, hence more akara balls were produced per batch of cowpea flour. The end product was less firm, had a slightly darker color, and the increased porosity caused an increase in the amount of frying oil absorbed. Compared to the Quillaja saponin, addition of the Yucca saponin to cowpea paste resulted in a product that was more desirable. The textural characteristics of akara obtained from the two saponins were comparable; however, due to the fact that the Quillaja saponin produced larger air bubbles, the product absorbed more frying oil. Whip time also had an effect on the paste and product characteristics. The longer the whip time, the higher the foaming capacity of the paste, hence the product was less firm and weighed less.

Due to increasing awareness of the dangers of consuming a high-fat diet, more and more people are consuming foods that have low or no fat. It was observed that addition of soy flour and curdlan significantly reduced the fat content of akara. Curdlan (1%) was more effective in lowering the fat content of akara (30% reduction) than soybean flour. However, addition of soybean flour resulted in the added benefit of increasing the protein content of akara. In contrast to curdlan, addition of soybean flour did not significantly affect the texture of akara. To obtain a greater reduction in the fat content, both soybean flour (20%) and curdlan (1%) were incorporated into the cowpea flour. This resulted in a 50% reduction in the fat content of akara made from 61% moisture pastes. However, this also resulted in increased firmness of akara due to a reduction in the foaming capacity of the paste. To combat this, the paste moisture content was increased to properly hydrate the cowpea proteins and develop a product with physical characteristics comparable to the control. This was effective in increasing the foaming capacity of the paste and reducing the firmness of the akara. A more desirable product was obtained at 63% paste moisture content. The fat content of the 20% soy/1% curdlan product was reduced by 35% compared to the control, the paste had similar flow properties, and the product firmness was also similar to the control. It, however, had the added benefit of being a more nutritious product due to reduced fat content and increased protein content.

These results indicate that saponins can be used to obtain a soft, spongy-textured product, and curdlan and soybean can be used to improve the nutritional quality of akara while maintaining its desirable physical properties. Because soy proteins increase water absorption and tent to retain water in finished food products, the frying time for soy-supplemented akara may need to be increased to ensure that the finished product is completely cooked. The high moisture content of akara made from 20% soy plus curdlan also suggests that cooking time may need to be greater than the 3 min period used in this study. Future research should include a sensory test to determine consumer response to the reduced-fat akara.