PROCESS DEVELOPMENT TO ENHANCE UTILIZATION POTENTIAL OF

AKARA

BY

SARA PAGE PATTERSON

(Under the direction of Dr. R.D. Phillips)

ABSTRACT

This research had three purposes: to investigate acceptability of akara prepared with three cowpea cultivars, to reduce the fat content of akara, and to make akara more convenient for the foodservice industry. There were no significant differences in akara acceptability among cultivars.

California Cream cowpeas were used throughout the rest of the research. To reduce akara’s fat content, a high amylose cornstarch and extruded cowpea flour were used. Cornstarch lowered the fat by 26% and cowpea flour lowered it by 36%. Samples were acceptable to American consumers with acceptability ratings of 6.1 to 7.4 (like slightly to like moderately).

Results for twice-fried akara show that fat content was higher than traditional akara. These samples were darker, tougher and had thicker crusts than in previous studies. Samples were partially cooked and quick frozen in liquid nitrogen and then finish fried. Internal temperatures ranged from 66ºC to 96ºC depending on variables.

INDEX WORDS: Akara, High-amylose cornstarch, Gelatinization, Extruded cowpea flour, Fat reduction, Frying, Sensory evaluation
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INTRODUCTION

Cowpeas (*Vigna unguiculata*) are highly nutritious legumes providing much needed protein, fiber, and B-vitamins to the diet. Most of the world’s cowpea production, about 80%, is produced in West Africa where cowpeas are eaten on a daily basis in foods like soups, moin-moin, and akara. The use of cowpeas in the United States is limited to that of a boiled vegetable.

Much research has been done to increase the consumption of cowpeas in the United States. One method was by processing cowpea flour. The use of cowpea flour would make using cowpeas a lot more convenient because instead of having to soak, decorticate, boil and/or grind the cowpeas, all that would be necessary would be to reconstitute the flour with water as needed. Studies have been conducted using cowpea flour as an ingredient in snack chips, doughnuts, cookies, breads, and many other food products. This has the potential to increase cowpea consumption in the U.S. while also increasing the nutritional value of these foods because of the protein content in cowpeas.

Akara is a West African fried finger food made from cowpeas that is usually eaten as a breakfast and/or a snack food in Africa. Much research has been done on producing akara that is acceptable to Americans. Acceptable ratings by consumer panelists for akara indicate potential for marketing akara in the United States.

Most of the research at the University of Georgia has dealt with producing akara from cowpea flour instead of the traditional wet-milled paste. Akara made with the flour is more dense than the traditional product. Throughout this research, the wet-milling process was used. The first objective of this research was to determine the acceptability
of akara prepared from the whole seed. It was also necessary to determine if one cultivar was preferred over another. The traditional product is made from black-eyed seeds that have been decorticated to remove black pigments and seed coats that are not preferred by West Africans.

There are many different varieties or cultivars of cowpeas available, but three were used for this study including a white-eye cultivar (California Cream), a black-eye cultivar and Kunde Giraffe (a smaller black-eye type). The California Cream cultivar was used so that akara could be produced with a creamy white interior that would be similar to that of the traditional akara. Using the all-white type would retain the seed coat and eliminate the decortication step in processing.

The second objective was to lower the fat content of akara. Since akara is a deep-fat fried food, the fat content is very high (about 31% on a dry basis). Obesity is very much on the rise in the United States, therefore, it would be beneficial to market a lower fat version of this product. Earlier research tried the addition of soy flour and/or an application of edible coatings such as methylcellulose to produce an acceptable low-fat akara. However, ratings were lower than those for the higher fat akara.

The method employed in the present research was the use of additives. A high amylose cornstarch and extruded cowpea flour were used in order to determine their effects on the fat content of akara. Both of these ingredients have been shown to have good water holding abilities.

The last objective was to determine if akara would be a suitable product for the foodservice industry. Previous studies focused on akara that was fully cooked, frozen, and ready to reheat in a conventional oven. This was intended to target the home use of
akara for consumers desiring to avoid the inconvenience of frying food at home. The foodservice industry, however, uses a lot of individually quick frozen (IQF) foods that are batch-fried directly from the freezer to the fryer. This research studied partially cooked and fully cooked samples that were frozen in liquid nitrogen in order to quick freeze the samples. The samples were then finish fried or reheated in hot oil (177°C) directly from the freezer. This frying temperature is commonly used in the foodservice industry.
SECTION I

LITERATURE REVIEW
Cowpea

Cowpeas (*Vigna unguiculata*) are considered an important legume in West Africa where about 80% of the world supply is produced (FAO, 2000). Some other common names are blackeyed peas, southern peas, crowder peas and chinapeas. Cowpeas 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). The four major groups in the United States are blackeye, crowder, purple hull, and cream types (Prinyawiwatkul et al., 1996).

Legumes are among the most adaptable of plants. They are found in a wide variety of climatic zones and can be stored for extended periods of time (Phillips, 1993; Taiwo, 1998). They are popular because they are low in cost, easily available, and are very versatile (Uzogara and Ofuya, 1992) in food applications. Cowpeas are predominantly hot-weather crops that prefer temperatures between 20ºC and 30ºC. They are, however, vulnerable to insects and this leads to a lower yield when compared to cereals. In fact, cereals production range is about 1700kg/ha whereas legumes are about 1/2 of that (Aykroyd et al., 1982; Salunke et al., 1985). Cowpeas are also able to fix nitrogen and can be planted along with other crops.

Cowpeas are a good source of nutrients because they are high in protein, fiber, B-vitamins and other nutrients such as calcium, magnesium, iron, potassium and zinc (Uzogara and Ofuya, 1992; Aykroyd et al., 1982). This is especially important in Nigeria since malnutrition is a major problem in that area of the world. With the increasing prices of animal protein, legumes provide a cheaper source of protein than meats.
Cowpeas are high in proteins ranging from 21-35%. The major storage proteins of legumes 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). However, they are high in lysine and low in sulfur-containing compounds. Cereals, however, are low in lysine and high in sulfur-containing compounds making them good complements to cowpeas.

For women aged 19-24, a 100g serving of cowpea provides about 51% of the Recommended Daily Allowance (RDA) of protein and 52% of the RDA of fiber. Also, about 352% of the RDA for folate is found in 100g that makes it very beneficial for women--especially those that are pregnant. Many foods such as cereals and grain products have been fortified with folic acid to lower the risk of having a pregnancy affected by birth defects (Rader et al., 2000).

Plant proteins are said to have cholesterol-lowering abilities (Taiwo, 1998) and the diet should include fiber-rich foods like legumes, fruits and vegetables (Anderson and Hanna, 1999). The fiber and protein found in legumes both have positive affects on serum cholesterol (Phillips, 1993). Cowpeas are also very low in fat (about 1.9%). A daily consumption of 100-135g of dry beans can lower cholesterol level by about 20% thus lowering the risk of coronary heart disease by about 40% (Anderson, 1985; Johnston et al., 1983).

Even with the many benefits of cowpeas, they are underutilized in the United States. The primary way cowpeas are consumed in the U.S. is in the form of a boiled
vegetable and this has limited their use in the American diet. Other areas of the world such as West Africa use the cowpea in various ways, e.g., soups, cakes, pies, rice dishes and in infant cereal-based foods. Cowpeas are also used in akara (fried cowpea paste) and moin-moin (steamed cowpea paste).

**Limitations**

*HTC Defect*

Even though the cowpea has many nutritional benefits, there are problems with their consumption. One constraint of cowpea consumption is what is called the Hard To Cook (HTC) Defect. This is where the seeds resist softening during cooking (Liu et al., 1992). Storage and processing conditions are important when trying to reduce the HTC defect because high temperatures (30ºC-35ºC) and/or high humidity (60-80%) can cause this problem to occur. In normal seeds, most of the protein is water-soluble. In the defected seeds, however, most is water-insoluble. This can lead to coagulation, which can cause water-resistant barriers resulting in HTC seeds (Liu et al., 1992). Unfavorable storage conditions cause cells to fail to separate after cooking (Jones and Boulter, 1983). The HTC defect not only causes textural changes, but nutritional quality is also affected because the availability of essential amino acids decreases (Tuan and Phillips, 1992).

There is also what is called the Hard-Shell Defect. This differs from the Hard-to-Cook defect in that the Hard-Shell occurs because the seeds are unable to absorb water when soaking. The Hard-to-Cook defect does not allow the seeds to soften during cooking. The Hard-to-Cook phenomenon is more chemical-related whereas the Hard-Shell is more physical-related (Uzogara and Ofuya, 1992).
Digestibility

Digestibility problems also occur with cowpeas. Oligosaccharides such as raffinose, stachyose and verbascose are present in legumes and are said to be responsible for flatulence (Fleming, 1981). This is because humans lack the enzyme galactosidase, which breaks down these sugars in order for them to be digested. Other anti-nutritional factors present in cowpeas are trypsin inhibitors and tannins. Legume tannins and trypsin inhibitors are reported to decrease protein digestibility (Plahar et al., 1997) by binding to and inhibiting the action of digestive enzymes (Phillips, 1993). Carbonaro et al. (1997) suggests that aggregations of legume proteins during heating could be a cause of the low digestibility of cooked legume proteins. However, cooking cowpeas does improve the protein efficiency ratio (Phillips and Baker, 1987). These authors show that the PER of raw cowpeas is 2.04, fried akara had a PER of 2.68, and samples that had been extruded had a PER as high as 2.81.

Processing

Another constraint of cowpeas is the laborious processing steps involved in producing foods containing cowpeas. Even if only eating cowpeas as a boiled vegetable as we do in the United States, the process involves pre-planning, soaking and/or boiling for extended amounts of time. Sometimes it is necessary to remove the seed coats. Products like akara and moin-moin require decortication because a creamy white interior is desired. Decortication produces a more desirable colored product, and it reduces the occurrence of flatulence caused by the fiber and cellulose present in the seed coats. However, some protein, calcium, niacin, and dietary fiber is lost (Nnanna and Phillips,
In order to remove the seed coats, the seeds have to be soaked to loosen the seed coats and then manually rubbed or mechanically abraded to remove them.

**Akara**

Akara is a popular West African food made from cowpea paste which has been whipped into a batter, seasoned with ingredients like chopped bell peppers, chopped onions, and salt and then deep-fat fried in hot oil (193°C). This product resembles what we Americans know of as the hush puppy (fried cornmeal balls) with a crisp outer layer and a bread-like interior. However, akara has a lighter, spongier texture because of the air that has been incorporated into the batter during whipping.

Akara is relatively unknown here in the United States, but in West Africa and other countries it is widely consumed either as a breakfast food or as a snack food. There are various names given to this product depending upon the area of Africa where it is consumed. Some of the names are koose, kosai, akla, and accra. There has been considerable research conducted by the University of Georgia to determine the acceptability of akara in the United States. This research showed promising results with acceptable sensory ratings by teenagers (McWatters et al., 1997) as well as older consumers (McWatters et al., 1990). However, akara needs to be targeted to certain sectors of these population groups because demographic factors such as age, race and education play an important part in determining the acceptability of this product (McWatters et al., 1990).

The major limitation for akara is that the traditional product-making process is very time-consuming. The process includes first soaking which softens the seeds and makes the decortication step easier, dehulling which removes the seed coats and black
specks associated with blackeyed peas, wet milling to produce paste, and then frying to achieve the crispy texture and brown color associated with akara. This is all very time-consuming and inconvenient, therefore, research has been conducted on simplifying the akara-making task. One reported method has been to produce akara from cowpea flour or cowpea meal. This way, the soaking, dehulling, and particle size reduction steps required for each batch are eliminated, allowing akara to be made simply by reconstituting milled flour. A collaborative effort has been conducted by The University of Georgia and The University of Nigeria through the Bean/Cowpea Collaborative Research Support Program (CRSP) in order to produce acceptable cowpea flour (Prinyawiwatkul et al., 1996).

**Functionality**

*Temperature*

It has been found that many factors affect the functionality of the paste made from flour including hydration time, drying temperature and particle size. These parameters affect factors like foaming capacity and paste handling properties that, in turn affect the overall texture of akara. With respect to temperatures and their affect on the functional properties of a paste, studies have been conducted by Phillips et al. (1988) to determine the optimum temperature for drying cowpeas. Drying seeds that have been wetted and conditioned for mechanical seed coat removal is a pre-decortication step which precedes cowpea meal preparation. High drying temperatures (110 and 130°C) show reduced water holding capacity, adversely affecting the functionality of the paste prepared from this meal. McWatters et al. (1988) found that with pre-decortication temperatures of 110
and 130°C, the paste did not float when dispensed into hot oil and did not form separate balls.

*Particle size*

Complaints about akara made from flour have been poor water absorption of the flour and production of akara balls that were heavy, lacked crispness and lacked the cowpea flavor normally associated with akara made from fresh paste (Dovlo et al., 1976). Finely milled cowpea flour has a very small particle size and thus less water holding capacity than coarsely milled flour or meal. This is very important when forming a stable cowpea-based foam system because all of these factors affect the paste handling characteristics. The paste handling characteristics affect how well the product handles and how well it forms the ball shape when fried.

Another method studied to save preparation time is the use of whole (non-decorticated) seeds. This process eliminates the dehulling process altogether, retaining the seed coat in the cooked product. The appearance of akara made from non-decorticated blackeye seeds is not desirable to West Africans because of the dark color imparted by the blackeyes that are still present. However, akara made from both decorticated and non-decorticated blackeyes received acceptable sensory ratings by American teenagers who had never seen the product before and therefore had no preconceived bias about it (McWatters et al., 1993). Using cream-type cultivars (white-eye) can improve the appearance of akara while still retaining the seed coat.

*Foaming properties*

The foaming properties of cowpea paste are very crucial in developing a product with the textural characteristics associated with akara. A foam consists of a dispersion of
gas bubbles in a liquid (Damodaran, 1996). Whipping is the most important step in incorporating air into the paste. Because of the airiness of the paste, the paste floats when dispensed into hot oil and the akara has a light, spongy texture.

Several factors determine the foaming ability of cowpea paste including particle size, hydration time, protein content, and protein solubility. Proteins are not only important nutritionally, but they also determine the air-holding capacity of a foaming agent. Proteins contribute such things as solubility, water binding, rheological behavior, foaming and whipping ability (Giese, 1994). In order for a protein to provide a good foam system, it needs to be able to absorb at the air-water interface during whipping, undergo quick arrangement at the interface and form a cohesive viscoelastic film (Damodaran, 1994).

Research has been done on how pH, ionic strength, and temperatures affect the solubility of proteins. If protein solubility is affected, then foaming ability can also be affected. Foaming capacity has been shown to increase as the pH and ionic strength increase (Aluko and Yada, 1995). The same authors conclude that at a high pH, hydrophobic forces decrease and the proteins are more flexible and can adsorb to the air-water interface to trap air.

The stability of the foam also increases at a higher pH. Foam stability is a measure of how long it takes for the liquid portion to drain from a foam. It has been shown that akara paste has the best functional properties when used immediately or within 30 minutes (Hung and McWatters, 1990), however, it is still acceptable up to 60 minutes. Paste viscosity is also important when determining foam stability. If a paste is
viscous, it prevents the liquid from draining and, therefore, increases foam stability (Damodaran, 1996).

**Frying**

Besides the inconvenient process of producing akara, the cooking method is frying which results in a high-fat end product. Therefore, the fat content may be another limitation for the marketing of akara. Research by Huse (1996) on the reduction of fat content in akara by the use of soy flour and edible coatings found that addition of 6% soy flour produced an acceptable product that was lower in fat whereas akara made with edible coatings was not acceptable. Akara is a porous product that does not allow for an even application of the coatings.

Frying of foods is an age-old process that gives certain foods unique flavors and textures (Singh, 1995). Fried foods are very popular in the United States because of their sensory characteristics and their convenience. The snack food and fast food markets offer many fried foods such as french fries, potato chips, fried chicken, etc. that Americans enjoy immensely.

Frying is a difficult operation to understand, and therefore, difficult to imitate. Many variables such as oil temperature, product composition, oil quality, oil absorption and other factors affect the quality of the end product. The frying mechanism has been studied on various foods in order to try and understand what is happening in a food while immersed in hot oil.

Oil uptake is a major area of concern since obesity in the United States continues to increase. It is recommended that an individual keep his/her daily fat consumption below 30% of the total caloric intake (WHO, 1990). This is because excess fat
consumption is believed to increase the risk of coronary heart disease and even some cancers (Browner et al., 1991).

Mechanism

Deep fat frying involves both heat and mass transfer (Krokida et al., 2000). It is a complex process that occurs when the heat from the oil passes through the food and moisture from the food evaporates. When the moisture leaves the food, oil is absorbed by the food (Paul and Mittal, 1997). The frying process involves both convective heat and conductive heat. Convective heat is the heat transferred through the oil and conductive heat is the heat transferred through the food (Orthoefer et al., 1996).

It is very important to use optimum conditions when frying. Factors like oil quality, frying temperature, length of frying, product shape, moisture content, porosity, surface treatments and crust formation affect oil absorption in a food. Fried food can absorb as much as 490g oil/kg (Mohamed et al., 1998).

Using good quality oil and the correct temperatures will maximize the quality of the product, however, sometimes it is very difficult to monitor oil quality. In order to maintain good quality oil, the food industry uses filters and/or antioxidants to slow down the deterioration of the oil. Many times, cooks in restaurants will use visual observation of color, odor, foaming and smoking to determine the quality of the oil (Paul and Mittal, 1997). However, these observations are subjective and are not the most reliable methods.

According to Paul and Mittal (1997), oil goes through many changes when heated. There are several stages that lead to the deterioration of oil. In the first stage, very little oil is absorbed by the food and the oil is a raw, white-colored product that is usually considered fresh oil. In the next stage, browning begins. The third stage is the
optimum frying oil where the golden brown color evolves with a crisp surface. The oil then begins to degrade in the next stage, causing excess oil absorption; the oil then goes into what is called "runaway oil." “Runaway oil” is oil that causes the product to get excessively oily and off flavors are present. Prolonged use of a fat is commonly practiced, so regular skimming of crumbs, filtering, replenishing with fresh fat and regular cleaning of the fryer are necessary in maintaining the oil quality (Mehta and Swinburn, 2001).

Monitoring of oil quality is necessary because oil degradation is a process which can produce compounds that can be harmful. Reactions take place during frying because high temperatures are used and these reactions depend on the temperatures, duration and aeration (Clark and Serbia, 1991). These are chemical reactions such as oxidation, polymerization, and hydrolysis.

The type and shape of the food being fried largely affect the oil uptake. The moisture content of the food is also a major factor influencing the amount of oil absorbed. Some research has shown that higher initial moisture content results in a higher fat uptake (Gamble and Rice, 1988; Lulai and Orr, 1979). However, other studies show that the opposite is true. Wheeler and Stingley (1963) state that doughnuts with a higher moisture content resulted in a lower fat product. Therefore, it is very important to understand how a particular food reacts with the oil.

Another factor that is important is the crust layer. A crust forms on most foods while frying and this is where most of the fat is localized (Gamble et al., 1987; Farkas et al., 1992; Keller et al., 1986; Pinthus et al., 1995; Varela, 1977). When potato chips have been studied with respect to oil uptake, it has been shown that little fat absorption is
taking place while immersed in the hot oil. Most of the oil uptake occurs when the chips are removed from the fryer--during the cooling period (Moreira et al., 1997; Ufheil and Escher, 1996; Moreira and Barrufet, 1998).

This phenomenon has been explained in part by Gamble et al. (1987). The internal pressure changes when the product is removed from the fryer. This causes the vacuum to pull in excess oil through the damaged surfaces or the pores of the crust. Banks (1996) has stated that if the temperature that the food leaves the oil can be maintained, reduced oil absorption could be obtained. The same author comments that some processes involve the use of a stream of heated air for the prevention of excess surface oil, but dry steam prevents oxidation. Also, the use of centrifugal force to reduce oil absorption is used in some operations (Banks, 1996).

The viscosity of the oil is also crucial because it has been shown that the higher the viscosity of the degraded oil, the more oil is absorbed by the food. In research conducted by Paul and Mittal (1997), potatoes absorbed about 8.5% oil when fried in fresh oil whereas potatoes fried in degraded oil absorbed up to 15%.

**Food Trends**

Fried foods are very popular among consumers in the United States. In fact, french fries are the favorite way of eating potato. Fried foods account for many of the top best-selling items on menus (Banks, 1996). According to the U.S. Department of Statistics, fried foods really haven't been affected by the increased concern of reducing one's fat intake. Frying imparts certain flavors and textures that can't be achieved any other way.
Batch fryers are used a great deal in the food industry. This is because of their versatility in handling a wide variety of food products (Banks, 1996). According to the same author, there is a temperature range of 325°F-375°F that is considered normal in the food industry. Banks states that high temperatures tend to provide thick crusts; Orthoefer et al. (1996) comments that low frying temperatures can lead to a product with increased oil absorption and a greasy appearance. Therefore, determining the optimum temperature for each product is ideal.

*Fat Reduction in Fried Foods*

From the year 1985 to the year 1995, the percentage of overweight people rose from 29% to 34% (Binkley et al., 2000). As Browner et al. (1991) stated earlier, obesity can lead to many health problems. Obesity affects more than just the person with this disease--it also effects the economy. The cost of obesity in 1994 was about $12.7 billion (Thompson et al., 1998). Therefore, lower-fat options in the market are needed not only to live healthier lives, but to also help the economy.

To try to reduce fat consumption, food scientists are developing methods to reduce the fat content in popular fried foods. This is not an easy task because of the many variables responsible for oil absorption. Frying gives foods certain textures and flavors that are almost impossible to mimic. Nevertheless, ingredients such as rice flour, peanut flour and soy flour have been studied and have shown some promise in fat reduction.

Doughnuts have been one food formulated with soy flour, cowpea flour, and modified starches (Martin and Davis, 1986; Shih et al., 2001). Wolf and Cowan (1971) state that soy flour’s ability to reduce fat content could be because of the denaturation of
proteins. The denaturation causes film barriers that block the uptake of excess oil. Also, during cooking, starch goes through a process called gelatinization that can increase the retention of water in a product. The use of fat substitutes such as Olestra has also been implemented. Olestra (Olean) is a calorie-free fat that is not absorbed by the human body. It has been used in the frying of potato chips as seen in the "WOW®" chips from Frito-Lay, Inc.

Another technique to reduce the fat content of fried foods is the use of edible coatings. Edible films or coatings can be generally defined as thin layers of edible materials applied on the surface of foods in order to act as a barrier (Gennadios and Weller, 1990). They have been used to extend the shelf life of a food product as well as to act as a barrier to oil absorption. These coatings are hydrophilic and therefore, bind water and prevent oil absorption (Priya et al., 1996). Additives such as gelatins, starches and cellulose derivatives have been used in this manner. Although these ingredients and/or methods have had an impact on fat reduction, full-fat fried foods still dominate. The textural characteristics of the reduced fat versions still do not match those of the full-fat product.

Lower fat foods have been on the increase in attempts to control health problems, but this is a challenging feat for scientists. Providing a low-fat food with sensory properties equivalent to those of a full-fat product is very difficult. Substances such as fat replacers and sugar substitutes have also been included in foods in order to achieve fat and/or calorie reduction (Sandrou and Arvanitoyannis, 2000).

Food components in a food such as amounts of starch and protein can have an effect on physical and/or chemical properties of foods. Starch is the predominant
carbohydrate providing about 70-80% of the calories consumed by humans (BeMiller and Whistler, 1996). Starch is composed of two polysaccharides--amylose and amylopectin. Amylose is a linear molecule consisting of long chains of glucose units linked by $\alpha$ 1-4 bonds. Amylopectin, however, is a branched molecule of glucose units linked by $\alpha$ 1-6 bonds.

During cooking, starch gelatinizes and this has an effect on functional properties of foods. Starch gelatinization is the disruption of order in the granules (BeMiller and Whistler, 1996) and can be caused by heat. Granules swell and the starch molecules become more soluble in water therefore increasing the paste viscosity. Starches are used a great deal in foods in order to help retain water and obtain viscous fluids (BeMiller and Whistler, 1996). When foods are able to retain water, this can cause less oil absorption during frying.

Proteins are also major components of foods especially in cowpeas. Proteins are complex polymers that consist of 20 different amino acids (Damodaran, 1996). The differences among proteins are the sequence of these amino acids. Food proteins serve many roles in food both nutritionally and functionally. Some functions of proteins are gelation, foaming, emulsification and water binding. Milk, meats, eggs, legumes and oilseeds are the major sources of proteins (Damodaran, 1996).

Amide bonds hold proteins together and the side chains determine the degree of solubility with water (Damodaran, 1996). Stability of proteins depends on forces such as steric strains, Van der Waals, electrostatic and hydrophobic interactions (Damadoran, 1996) and these forces cause folding of proteins into either primary, secondary, tertiary or quarternary structures. The cooking process can cause proteins to unfold and go through
denaturation. Denaturation has been described as a process in which the spatial arrangement of polypeptide chains changes from ordered to a less ordered state (Kilara and Harwalker, 1996). It has been stated by Wolf and Cowan (1971) as well as Mohamed et al. (1995) that denaturation of proteins could cause there to be less absorption of oil after frying.

**Extrusion**

Food extrusion is a cooking process that uses high temperatures, shear, and short time in processing. Extrusion is now used to process many foods such as pasta, ready-to-eat cereals, snacks, biscuits, and meat-like products (Harper, 1989). The extruder has gained in popularity because of its versatility in doing several steps in one (Harper, 1989).

Single screw extruders have been available since the 1940’s whereas twin-screw extruders were developed in the 1970’s. Twin-screw extruders have more advantages than the single screw extruder in the food industry because it can handle a wider variety of ingredients (Harper, 1989). The extrusion process involves many parameters such as screw speed, die configuration, and feed rate. All are parameters that provide certain characteristics depending on the residence time of the material, temperature of the barrels, and the ingredients being extruded.

Many changes occur during extrusion due to the heat and shear of the system. Starch gelatinization and protein denaturation are two chemical changes that have been extensively studied with respect to the changes in the functionality of the ingredients that have been modified by extrusion. Starch and protein are very common in many foods. Therefore, it is imperative that the changes they undergo during cooking be understood.
Convenience Foods

Another trend besides low-fat food is that of convenience. Convenience is said to be the driving force of the future (Sills-Levy, 1989). People lead busy lives and have little time to prepare traditional meals, therefore, the availability of meals that are easy to prepare such as frozen meals is increasing. There are an increasing number of frozen entrees or one-dish meals available that take very little time and energy to prepare. Frozen meals and pizzas like Stouffer's®, Tombstone's®, etc. are popular. There are also frozen meals that are low-fat such as Lean Cuisine®, Healthy Choice®, and Smart Ones®. These offer low-fat as well as convenience. There are also shelf-stable meals such as Hamburger Helper®, Tuna Helper®, and Campbell's® Oven Bakes, etc. that only require the addition of a meat ingredient.

Consumers are also eating out often. According to Blaylock et al. (1999), food away from home provided about 34% of the total caloric intake in 1995. This has increased dramatically from 19% in 1977. In fact, the percentage of money spent on foods away from home rose from 26% to 39% (Putnam and Allshouse, 1996) of the total food expenses.

Because of some of these trends, obesity is increasing in the United States. People not only eat to live, they eat for pleasure as well (Blaylock et al., 1999). Eating has become very social and maintaining a balanced diet is challenging when a majority of meals are eaten away from home. This is because knowing the nutrient content of restaurant foods is difficult. Foods away from home provide more fat, cholesterol, and sodium as well as less fiber and calcium (Lin and Frazao, 1997; Lin et al., 1999). The restaurant serving sizes are also getting larger and larger. In fact, "super-sizing" value
meals have become very popular because the "get more for your money" slogan is being implemented (Liebman and Schardt, 2001).

Freezing

The convenience of many food items like french fries, chicken, and vegetables has been enhanced by providing partially or fully cooked frozen versions that could be finish-cooked at home or in foodservice establishments. Freezing involves the reduction of the temperature of a food product below the freezing point (Fellows, 1996). An end temperature of -18°C is the target when freezing foods (Canet, 1989). Food quality is affected by freezing because of damage done due to formation of ice crystals. Ice crystals form after the latent heat of crystallization is removed. According to Fellows (1996), in slow freezing large ice crystals form and deform and rupture cell walls. However, fast freezing results in smaller ice crystals, which damage the cell structure of the product less because the water vapor pressure gradients are not formed. Therefore, much of the textural quality is preserved. Many of the frozen foods on the market are individually quick frozen (IQF).

There are several types of freezing methods and equipment that are categorized into either mechanical refrigerators or cryogenic freezers (Fellows, 1996). Each have different rates of freezing and this should be taken into consideration when choosing a particular method for certain products. According to Fellows, slow freezers have a rate of 0.2cmh\(^{-1}\) and include still-air freezers and cold stores. Quick freezers have a rate of 0.5-3cmh\(^{-1}\) and include air-blast and plate freezers. Rapid freezers have a 5-10cmh\(^{-1}\) rate of freezing and include fluidized bed freezing. Ultrarapid freezers have the quickest rate of freezing (10-100cmh\(^{-1}\)) and include cryogenic freezers.
Cryogenic freezing involves the use of cryogens that come in contact with a food and remove the energy quickly (Fellows, 1996). Two very common cryogens are liquid nitrogen and liquid carbon dioxide. Both have a high rate of freezing, which is an advantage when wanting smaller ice crystals in a frozen product. Both liquid nitrogen and liquid carbon dioxide have low boiling points that make them ideal for freezing foods quicker than other methods (Kim and Hung, 1994). Liquid nitrogen has a low boiling point of -196°C. There are also the advantages of less moisture loss during freezing and lower maintenance costs (Kim and Hung, 1994).

Quick freezing does have the disadvantage of cracking or splitting due to thermal shock (Fellows, 1996). Internal stress can cause food materials to shatter and this is an irreversible result (Kim and Hung, 1994). Therefore, it is important to determine which method optimizes the quality of the finished product.

**Increasing the utilization potential of akara**

The following research deals with increasing the potential for utilization of akara in the United States. Since obesity is a problem in the United States, it would be ideal to market akara in a reduced fat version. If the fat content of akara can be lowered while retaining the sensory characteristics associated with the product, it would provide a more healthy way to market this product.

With convenience being such a needed factor in everyone’s lives today, it would be helpful to provide a way for the foodservice industry to utilize this product. Eating away from home is becoming more and more popular, so providing akara in a form that can be finish-fried in the foodservice establishment itself would be beneficial. If akara is available in both ways—as a partially cooked product to be reheated at home in a
conventional oven or as a partially cooked product to be finish-fried in the foodservice establishment—it could be a more convenient product for the American consumer.

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sources on the characteristics of sponge cakes, rice cakes (apam), doughnuts and  
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water-soluble vitamin content of germinated cowpeas (Vigna unguiculata).  Plant  
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SECTION II

PHYSICO-CHEMICAL PROPERTIES AND CONSUMER ACCEPTABILITY OF AKARA (FRIED PASTE) MADE FROM THREE COWPEA CULTIVARS

*Patterson, S.P., McWatters, K.H., Hung, Y.-C., Chinnan, M.S., and Phillips, R.D. Accepted for publication by Food Research International.
Abstract

Akara, fried cowpea paste, is a popular West African food. Targeted to the U.S., it would provide a novel form for the use of cowpeas. The objective of this study was to assess the acceptability of akara by Americans who are regular consumers of fried foods. Cultivars used were California Blackeye, California Cream, and a 2:1 mixture of California Cream:Kunde Giraffe. Akara from California Cream, Blackeye, and the mixture contained 48.3, 47.2, and 49.6% moisture, respectively; 25.3, 23.0, and 24.9% protein, respectively; and 31.8, 32.1, and 30.4% oil, respectively. California Cream produced akara balls that were lighter in color (L*=48.0) than the other cultivars. Hue angles for each sample were 64.0 for Blackeye, 63.6 for California Cream and 61.2 for the mixture. Mean values for shear-compression force of akara balls ranged from 375 to 405N. Sensory acceptability was not significantly affected by cultivar. Akara from all cultivars had acceptable ratings.

Keywords: Akara; cowpeas; acceptability; proximate composition; physico-chemical properties
Introduction

Akara is a popular West African food made from cowpea paste which has been whipped into a batter, seasoned with ingredients like chopped bell peppers, chopped onions, and salt and then deep-fat fried. This product resembles what Americans know of as the hush puppy (fried cornmeal balls) with a crisp outer layer and a bready interior.

The akara-making process is very time consuming and tedious, and therefore, very inconvenient. The process includes soaking seeds and removing seed coats before preparing the batter. Therefore, several methods have been researched to determine if the process can be simplified. One method that has been investigated extensively is the use of rehydratable cowpea flour. This has proved to produce a heavier product than the traditional wet milling process because of the functional properties that are affected by factors such as particle size and hydration time. Akara made from flour, meal, or whole seeds differs in texture because of the foaming capacities of the paste (Kethireddipalli, 1999; Prinyawiwatkul, McWatters, Beuchat, & Phillips, 1996). This is caused by differences in average particle size (McWatters & Chhinnan, 1985).

Whipping is essential to formation of a foam, a dispersion of gas bubbles in a liquid, and helps to evenly distribute the air bubbles. Foaming properties are important to the textural character of akara as demonstrated by Kethireddipalli (1999); she showed that samples made from whipped flour paste had undesirable textural quality because of the inconsistency of the whipped paste. Other researchers have shown that different cowpea cultivars had different paste handling properties, frying characteristics, and akara-making quality depending on the moisture content of the paste (McWatters, Hung, Hung, Chinnan & Phillips, 2001).
Another method that would simplify the akara-making process would be to eliminate the decortication step (the process of removing the seed coats). This would decrease the time to prepare akara while at the same time still retaining the fiber present in the seed coat. Earlier studies have evaluated the consumer acceptance of akara and have shown that there is promise for this product in the market. In these studies, decorticated seeds were used and it was usually in the form of cowpea flour or meal. Because Americans have few preconceived perceptions of akara, there was reason to believe that decortication may not be necessary. The research done in this study used non-decorticated peas to determine the acceptability of akara by Americans who are regular consumers of fried foods while also determining if one cultivar was preferred over another. This was done comparing three cultivars of cowpeas using sensory evaluation by target consumers.

**Materials and Methods**

**Materials**

California Blackeye cowpeas were obtained from Twelve Baskets Sales and Marketing Inc., Mableton, GA. Kunde Giraffe cowpeas (a wild, short-season blackeye type that is insect and drought resistant) were provided by Inland Empire Foods, Riverside, CA; California Cream peas (an all-white type) were provided by The University of California, Riverside, CA. Green peppers, onions, and salt were purchased from a local grocery store.

**Akara Preparation**

Akara was prepared from 100% Blackeye, 100% California Cream and a 2:1 mixture of California Cream:Kunde Giraffe. Since Blackeye had 3.3% pigmented matter
in the whole seed and Kunde Giraffe had 6%, a 2:1 ratio of California Cream:Kunde Giraffe was used to mimic the traditional product made from 100% Blackeye. After conducting preliminary trials on scaling up from a 50 gram batch size, a 500 gram batch was used.

The first step was to soak 500 grams of peas in approximately 2500 ml tap water for three hours. After draining for five minutes, the cowpeas were then chopped in a Toledo chopper (model 5120-0-009, Toledo, OH) in order to reduce the particle size. The moisture content was then adjusted to 64% before blending for five minutes in a Waring blender (model 34BL22, New Hartford, CT)--scraping the sides of the blender jar with a rubber spatula every 30 seconds. The formula used to obtain the 64% moisture paste \[W_a=W_1(100-M_i/100-M_f)-W_s\] is a modified version of the equation in McWatters et al. (2001) where \(W_a\) is the amount of water needed to reach the target moisture content, \(W_1\) is the initial weight of the peas, \(M_i\) is the initial moisture content of the dry peas, \(M_f\) is the target paste moisture content and \(W_s\) is the weight of the soaked peas. In the research conducted by McWatters et al. (2001), \(W_1\) was divided by 1+R because they decorticated the seeds and the weight ratio of seed coat to cotyledon was approximately 0.05. In this research, non-decorticated seeds were used.

After blending, the paste was transferred to a mixing bowl and whipped for 1.5 minutes in a Hobart mixer (model N 50, Troy, OH) set at speed 3. Seasoning ingredients (9.5% chopped green peppers, 9.5% chopped onions, and 1.5% salt) were stirred together and added to the blended paste after whipping.

Once whipped, the batter was dispensed with a #40 (approximately 20mls) ice cream scoop into a Donut Mini-Matic Model DMM 110 (Belshaw Bros., Inc., Seattle,
WA) continuous fryer preheated at 193°C for 2 minutes--turning after 1 minute. Samples were removed from the fryer, drained on absorbent paper towels until cool, then placed in freezer bags and frozen at -18°C until the day of the consumer panels. The yield from each batch ranged from 70-74 akara balls.

**Viscosity Measurements**

Viscosity measurements of cowpea paste at room temperature (23°C) were taken after whipping and just before adding the seasonings. A Brookfield Viscometer (HATD model, Stoughton, MA) was used with the TC spindle operating at 10 rpm. The whipped batter was spooned into a U.S. standard dry measuring cup (1/4 cup, about 60 mls) and tapped ten times in order to remove excess air. The batter was then leveled with a spatula and the viscosity (Pa.s) was measured.

**Proximate Composition**

The compositional analysis was determined of the finished product. Samples were allowed to come to room temperature and ground in a food chopper (model KSM-2B, Woburn, MA). Moisture content was determined on 5g samples dried overnight in a vacuum oven at 70°C under 25mmHg (modified AOAC method 925.09, AOAC, 1995). The weight loss was then calculated to determine moisture content. Ash content was determined on 1g samples using an AOCS method Ba 5-49 (AOCS, 1970). Dried samples remaining from moisture analysis were used for fat analysis that was determined by overnight solvent extraction (about 16-18 hrs.) with petroleum ether using a Goldfisch apparatus (Labconco, Kansas City, MO). Nitrogen content was determined using the Dumas combustion method (LECO analyzer, model 602-600, Warrendale, PA) on the
defatted/dry samples. A factor of 6.25 was used to convert nitrogen to protein content (FAO, 1970).

*Color and Texture Measurements*

Instrumental color measurements of four locations on each akara ball were conducted with a Minolta Colorimeter (model CR-200, Osaka, Japan) calibrated with a brown reference tile ($L^* = 69.82$, $a^* = 19.17$, and $b^* = 31.75$). Hue angle was calculated as $\arctan(b^*/a^*)$. After color measurement, the same balls were used for texture analysis, using the Instron universal testing machine (model 1122, Instron Corp., Canton, MA) equipped with a Kramer cell attached to a 500 kg load cell. The instrument was operated at a crosshead speed of 50 mm/min and a chart speed of 100 mm/min. Peak force was determined for each sample and the results are reported in newtons. The akara balls ranged from 16 to 19g in weight and were centered under the blades for the measurements.

*Sensory Evaluation*

Untrained consumers ($n=45$) determined acceptability of the akara. Panelists were recruited from a database maintained in the Department of Food Science and Technology, Griffin Campus. Criteria for participation were: minimum age of 18 years, regular consumer of fried foods, not allergic to any food, and availability for the test.

Panelists used the standard 9-point hedonic scale to evaluate their liking of appearance, color, aroma, flavor, texture, and overall liking of each of the six samples (3 cultivars x 2 replications). Panelists also completed a consent form, a demographic form, and a short questionnaire on their consumption of fried foods.
Samples had to be served warm, therefore, all panelists received the same coded sample at the same time. However, the sample reheating order of the six samples was randomized. Samples were reheated from the frozen state in a conventional oven at 204°C (400°F) for 12 minutes and served warm in 2 oz. plastic soufflé cups. Each panelist was given lemon water (concentration of 18mls lemon juice to 1L water) and unsalted crackers to cleanse the palate between samples. Each panelist received an honorarium of $10 for their participation.

Statistical Analysis

Statistical analysis of proximate composition, sensory, color, and texture data was performed using ANOVA and LSD mean comparison procedures of the Statistical Analysis System (SAS, 1990).

Results & Discussion

Akara from the three cultivars was similar in moisture and ash content (Table 2.1). Moisture content ranged from 47 to 49% with the mixture of California Cream and Kunde Giraffe being the highest. Ash content was the same for all three samples. Fat content of akara ranged from 30-32%, which was not surprising for a fully fried food. Akara from the mixture was significantly lower in fat (30.4%) than akara made from California Cream or Blackeye. Protein content of akara differed among cultivars, with California Cream being highest and the mixture the lowest.

There were significant differences with respect to the instrumental color analysis of the samples (Table 2.2). Akara from California Cream was lighter (higher L*) in color than that from the other cultivars. The more yellow-orange hue of the California Cream akara
Table 2.1. Proximate composition of akara prepared from three cowpea cultivars

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>% Moisture</th>
<th>% Fat&lt;sup&gt;b&lt;/sup&gt;</th>
<th>% Protein&lt;sup&gt;b&lt;/sup&gt;</th>
<th>% Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Cream</td>
<td>48.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Blackeye</td>
<td>47.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>32.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mixture&lt;sup&gt;c&lt;/sup&gt;</td>
<td>49.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Values are an average of six measurements (two replications with three values each).

<sup>b</sup>Values in a column that are not followed by the same letter are considered significantly different at $\alpha=0.05$.

<sup>c</sup>These values are on a dry weight basis.

<sup>c</sup>The mixture is a 2:1 ratio of California Cream:Kunde Giraffe (a wild, short season blackeye type)
Table 2.2. Instrumental color and texture measurements of akara prepared from three cowpea cultivars\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>California Cream</th>
<th>Blackeye</th>
<th>Mixture(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunter L(^*)</td>
<td>48.0a</td>
<td>45.1b</td>
<td>43.1b</td>
</tr>
<tr>
<td>a(^*)</td>
<td>14.7a</td>
<td>12.0c</td>
<td>13.7b</td>
</tr>
<tr>
<td>b(^*)</td>
<td>30.5a</td>
<td>25.1b</td>
<td>25.5b</td>
</tr>
<tr>
<td>Hue angle</td>
<td>63.6ab</td>
<td>64.0a</td>
<td>61.2b</td>
</tr>
<tr>
<td>Shear Force (N)</td>
<td>405.0a</td>
<td>392.3a</td>
<td>375.1a</td>
</tr>
</tbody>
</table>

\(^a\)Any value in a row followed by a different letter is significantly different at \(\alpha = 0.05\). Hunter values are an average of four readings per ball (a total of 12 balls for each variety). L\(^*\) lightness, +a\(^*\) redness, -a\(^*\) greenness, +b\(^*\) yellowness and -b\(^*\) blueness, Hue angle = \(\tan^{-1}(b*/a*)\). Shear force values are an average of 12 measurements.

\(^b\)The mixture is a 2:1 ratio of California Cream:Kunde Giraffe.
was due to its greater redness (higher a*) and yellowness (higher b*). Visual observation confirmed a lighter, more golden color for akara from this cultivar than akara from the others. Results from this study showed a darker product than the earlier study conducted by McWatters et al. (2001). However, the earlier study removed the seed coat from all cultivars which could have resulted in a lighter-colored product. Akara texture was not affected by cultivar (Table 2.2) despite differences in foam viscosity.

Foam viscosities were 90.1 Pa.s for Blackeye, 82.9 Pa.s for California Cream, and 75.9 Pa.s for the mixture. Viscosity is an important factor in akara-making because it affects the functionality of the paste. The viscosity of the paste would determine the degree of gas dispersion in the foam (Hanselmann & Windhab, 1999). The functionality of the paste is important in producing balls with a uniform shape (Phillips & McWatters, 1991). When whipped, the paste forms a foam structure and this structure is critical in the achievement of the light, spongy texture associated with good quality akara (McWatters, Chinnan, Hung, & Branch, 1988).

In earlier studies by McWatters, Resurreccion, Fletcher, Peisher, & Andress (1993), viscosities of pastes from decorticated and non-decorticated cowpeas were compared. Paste prepared from non-decorticated peas was more viscous (higher yield stress, higher flow consistency index, lower flow behavior index) than paste from decorticated seeds. Whole seed paste was also more dense (higher specific gravity) than decorticated seed paste, slower to dispense, and produced fewer akara balls per batch. Since cultivars are known to vary in hydration time, cooking properties, percent seed coat, and milling behavior (Akinyele, Onigbinde, Hussain & Omololu, 1986; Demooy &
would also be assumed to affect product-making characteristics.

Sensory evaluation using consumer panels did not show significant differences among cultivars (Table 2.3), with all samples receiving acceptable ratings. The panelists were asked to complete two questionnaires during their session. One was a demographic questionnaire and the other inquired about their consumption of fried foods (Table 2.4). The panelists ranged in age from 18 to over 75 years with 51% being 55 or over. Most were female (78%) and white (84%). About 62% were married, 44% were high school graduates, and 20% had completed college or graduate school. About 47% were retired and one-third were employed full time. Household income was fairly evenly distributed among categories.

The panelists were regular consumers of fried products with 56% eating fried foods at least twice a week (Table 2.4). Taste was selected by 84% of the respondents as the most important attribute when eating this type of product followed by texture (27%) and nutrition (27%). Twenty-four percent of the panelists ate away from home once a day. Eighty-nine percent liked this product either moderately or very much and were more likely to eat this type of food at a restaurant or cafeteria (58%) than at home (36%) or at a fast food establishment (18%). Fat content of this product would influence purchase behavior for 56% of the consumers. If this product were available as a fully cooked, frozen product, 62% of the panelists would consider purchasing it; more would reheat it by microwave (56%) than by conventional oven (42%). If this product were available as a partially cooked, frozen product to be finish fried at home, 34% would
Table 2.3. Mean hedonic ratings for sensory quality and acceptability of akara prepared from three cowpea cultivars$^a$

<table>
<thead>
<tr>
<th>Attributes</th>
<th>California Cream</th>
<th>Blackeye</th>
<th>Mixture$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>7.6</td>
<td>7.2</td>
<td>7.4</td>
</tr>
<tr>
<td>Color</td>
<td>7.7</td>
<td>7.2</td>
<td>7.5</td>
</tr>
<tr>
<td>Aroma</td>
<td>7.1</td>
<td>6.8</td>
<td>6.7</td>
</tr>
<tr>
<td>Flavor</td>
<td>6.8</td>
<td>6.5</td>
<td>6.4</td>
</tr>
<tr>
<td>Texture</td>
<td>7.1</td>
<td>6.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Overall</td>
<td>6.9</td>
<td>6.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Acceptability$^c$ 1.2 1.2 1.2

$^a$Means for sensory attributes and overall liking are based on a 9-point hedonic scale with 1=dislike extremely to 9=like extremely. There were no significant differences found for any attribute at $\alpha=0.05$.

$^b$The mixture is a 2:1 ratio of California Cream:Kunde Giraffe.

$^c$1=yes, 2=no.
Table 2.4. Questionnaire for the consumption of fried foods.\(^1\)

<table>
<thead>
<tr>
<th>Fried Foods Consumption Data</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How often do you eat fried foods? (n=45)</td>
<td></td>
</tr>
<tr>
<td>Once a day</td>
<td>26.7</td>
</tr>
<tr>
<td>Once a week</td>
<td>24.4</td>
</tr>
<tr>
<td>Twice a week</td>
<td>28.9</td>
</tr>
<tr>
<td>2. What is the most important thing when eating this type of food? (n=45)</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>8.9</td>
</tr>
<tr>
<td>Taste</td>
<td>84.4</td>
</tr>
<tr>
<td>Texture</td>
<td>26.7</td>
</tr>
<tr>
<td>Aroma/odor</td>
<td>20.0</td>
</tr>
<tr>
<td>Nutrition</td>
<td>26.7</td>
</tr>
<tr>
<td>Other (doneness)</td>
<td>2.2</td>
</tr>
<tr>
<td>3. How often do you eat away from home? (n=45)</td>
<td></td>
</tr>
<tr>
<td>Once a day</td>
<td>24.4</td>
</tr>
<tr>
<td>Twice a day</td>
<td>4.4</td>
</tr>
<tr>
<td>More than twice a day</td>
<td>4.4</td>
</tr>
<tr>
<td>Once a week</td>
<td>26.7</td>
</tr>
<tr>
<td>Twice a week</td>
<td>31.1</td>
</tr>
<tr>
<td>4. Where are you most likely to eat this type of food? (n=45)</td>
<td></td>
</tr>
<tr>
<td>Fast food establishment</td>
<td>17.8</td>
</tr>
<tr>
<td>Restaurant/Cafeteria</td>
<td>57.8</td>
</tr>
<tr>
<td>Home</td>
<td>35.6</td>
</tr>
<tr>
<td>5. How do you like this product? (n=44)</td>
<td></td>
</tr>
<tr>
<td>Like very much</td>
<td>38.6</td>
</tr>
<tr>
<td>Like moderately</td>
<td>50.0</td>
</tr>
<tr>
<td>Dislike very much</td>
<td>2.3</td>
</tr>
<tr>
<td>Dislike moderately</td>
<td>4.5</td>
</tr>
<tr>
<td>Neither like nor dislike</td>
<td>4.5</td>
</tr>
<tr>
<td>6. Would the fat content influence your purchasing this product? (n=45)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>55.6</td>
</tr>
<tr>
<td>No</td>
<td>26.7</td>
</tr>
<tr>
<td>Maybe</td>
<td>17.8</td>
</tr>
</tbody>
</table>
Table 2.4 (continued).

<table>
<thead>
<tr>
<th>Fried Foods Consumption Data</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. If this product were available as a fully cooked, frozen product would you consider</td>
<td></td>
</tr>
<tr>
<td>purchasing it? (n=45)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>62.2</td>
</tr>
<tr>
<td>No</td>
<td>8.9</td>
</tr>
<tr>
<td>Maybe</td>
<td>28.9</td>
</tr>
<tr>
<td>8. If yes or maybe, how would you reheat it? (n=36)</td>
<td></td>
</tr>
<tr>
<td>Conventional Oven</td>
<td>41.7</td>
</tr>
<tr>
<td>Microwave</td>
<td>55.6</td>
</tr>
<tr>
<td>Other (e.g., hot-air oven, toaster oven)</td>
<td>11.1</td>
</tr>
<tr>
<td>9. If this product were available as a partially cooked, frozen product to be finish fried</td>
<td></td>
</tr>
<tr>
<td>at home, would you consider buying it? (n=44)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>34.1</td>
</tr>
<tr>
<td>No</td>
<td>36.4</td>
</tr>
<tr>
<td>Maybe</td>
<td>29.5</td>
</tr>
<tr>
<td>10. The nuggets you are evaluating are not yet available in retail markets but may be in</td>
<td></td>
</tr>
<tr>
<td>the future. If a 2-pound bag of frozen Tater Tots® costs $2.39, what would you be</td>
<td></td>
</tr>
<tr>
<td>willing to pay for a 2-pound bag of these frozen nuggets? (n=45)</td>
<td></td>
</tr>
<tr>
<td>More</td>
<td>13.3</td>
</tr>
<tr>
<td>Less</td>
<td>15.6</td>
</tr>
<tr>
<td>About the same</td>
<td>71.1</td>
</tr>
</tbody>
</table>

\(^1\)Percentages may not add to 100 due to rounding or may exceed 100 (questions 2,4,8) because some panelists selected more than one choice.
consider buying it. Panelists were informed that the nuggets were not yet available in retail markets but were compared in price to Tater Tots®, a frozen potato-based fried food; 71% of the consumers indicated they would pay about the same amount for the cowpea-based nuggets as for Tater Tots®. Panelists were also asked to comment on the type of food with which they would eat the nuggets; fish was mentioned by 40% of the participants.

Results from this study indicate that the United States could provide a potential market for the West African food akara. All three cultivars produced akara with acceptable sensory ratings, and there was no significant difference with respect to cultivar. Earlier studies on the acceptability of akara have also shown promise for this product in the United States. McWatters, Fletcher, & Resurreccion (1997) conducted a study using teenagers; they proved to be a potential market, with the mean overall liking ratings for akara ranging from 5.7-6.3 on a 9-point hedonic scale. Cowpea meal was used to prepare the akara in that study. Another study by the same authors (1990) showed that older consumers and those with a high school education or less could be a target market.

Because of the results found in these and other studies, demographic characteristics that need to be considered in order to target akara for specific markets include age, income, race, and educational level. If a more convenient method of preparing akara were available, this product would aid in providing Americans with a novel food containing more protein, fiber, and B vitamins than comparable fried vegetable-based foods.
Acknowledgements

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References


SECTION III

INCREASING THE UTILIZATION OF AKARA:
FAT REDUCTION

Patterson, S.P., Phillips, R.D., McWatters, K.H., Hung, Y.-C., Chinnan, M.S. To be submitted to Journal of Food Science.
Abstract

Akara, a fried finger food made from cowpeas, is popular in West Africa and has been shown to be acceptable to American consumers. Akara is, however, a high fat food (about 32%). We determined the effects of incorporating two modifiers, cornstarch or extruded cowpea flour, on akara fat content and consumer acceptability. The modifiers were used at the 10% level. Fat was reduced by 26.1% with cornstarch and by 36.8% with extruded cowpea flour. There were no significant differences in sensory ratings among samples. All samples received acceptable ratings (6=like slightly) for overall liking, thus showing potential for the success of lower fat akara.

Keywords: akara, oil uptake, gelatinization, cornstarch, extruded cowpea flour.
**Introduction**

Akara, a fried finger food made from cowpeas, is very popular in West Africa where it is often eaten as either a snack or breakfast food. Several consumer tests conducted in the Atlanta, Ga area have shown that akara is acceptable to U.S. consumers (McWatters and others 1990; McWatters and others 1997). Since the traditional process of akara-making, involving wet-milled paste, is very time-consuming and therefore very inconvenient, most of these acceptability assessments have been carried out with akara made from reconstituted cowpea flour instead of traditional wet-milled paste. Using cowpea flour makes the processing more convenient because it eliminates the steps of soaking and decortication (removal of the seed coats); thus all that is needed at the time of preparation is reconstitution of the flour with water.

McWatters (1983) reported that akara made from cowpea flour received acceptable ratings, but its texture was more dense than akara made from traditional wet-milled paste. This was attributed to cowpea flour consisting of smaller particles than wet-milled paste, thus decreasing its water-holding capacity. Water holding capacity is very important in the akara-making process because the water enables formation of a paste with appropriate viscosity and foamability. The whipping step incorporates air into the batter that enables the formation of nicely shaped balls that have a light, spongy texture (Mbofung and others 1999). Good foamability is characterized by an even dispersion of gas bubbles throughout a paste. Akara paste prepared from hydrated flour showed a great deal of air cells rising to the surface (Kethireddipalli 1999). Hydrated meal showed a closer relation to the control, but the wet-milled paste still showed better
foaming and water holding properties. The coarseness of the particles from the control could be a possible explanation (Kethireddipalli 1999).

Traditional akara is made from decorticated wet-milled peas. West Africans do not like the black specks and overall appearance of Akara made from non-decorticated blackeyed peas. Therefore, in order to obtain a product with a light colored interior, the seed coats and blackeyes are removed, usually by soaking and manual rubbing. Patterson and others (2002) found that there were no significant differences in sensory attributes of akara made from three cowpea cultivars. Therefore, using wet-milled paste prepared from California Cream cowpeas (a white-eye cowpea cultivar) can simplify akara-making by eliminating the decortication step yet still produce akara that has the light interior as seen in traditional West African akara.

Even though akara is a product that provides many nutrients such as protein, B-vitamins, and fiber, it is also very high in fat (about 32% on a dry basis). Despite the growing number of low-fat foods on the market, more and more Americans are overweight (Binkley and others 2000). Obesity leads to a decrease in life span because risks of developing certain diseases such as coronary heart disease, diabetes, and hypertension are increased (Thompson and others 1998). Therefore, making akara that is lower in fat than the traditional West African version could provide a product that would be more suitable for U. S. consumers.

Frying is a very old process that gives foods unique flavors and textures (Singh 1995). Frying produces certain characteristics in a food that are very difficult to obtain through other methods. Americans have a great affinity for fried foods as seen in the popularity of such items as french fries, potato chips and fried chicken. However, with
the high incidence of obesity in the United States, reducing the fat in fried products while still giving the "fried food characteristics" is an on-going challenge to the food industry.

One method used to lower the fat content of akara is the addition of soy flour. However, use of this flour resulted in a product with a tougher texture and a more beany flavor than akara made from cowpea only (Huse 1996). Lowering the fat content of akara has also been attempted by the use of edible films such as hydroxypropyl methylcellulose, methylcellulose, corn zein, and amylose. However, results showed that consumers did not find this product to be acceptable (Huse 1996).

Therefore, the approach taken in this study was to incorporate modifiers into the batter to decrease the absorption of oil into the food during frying. The modifiers used were a high amylose cornstarch (Hylon VII) and extruded (pre-gelatinized) cowpea flour. These modifiers were chosen because of their functionality in food systems. Starch has been used in a variety of low-fat products (Hermansson and Svegmark 1996). Shih and others (2001) used rice flour in fried batters and believe that the amylose content was responsible for the decrease in fat absorption. They also reported that fat reduction in doughnuts was greater with the use of gelatinized than ungelatinized flour. Also, since the moisture content of the initial paste affects oil absorption during frying, a sample with a lower paste moisture content and without a modifier was also tested.

**Preliminary Trials**

In an attempt to lower the fat content of akara, different cooking methods were evaluated. This was done without modifiers to determine if a lower fat version of akara could be prepared by using pre-cooking methods such as steaming and microwaving,
prior to frying. Preliminary trials were conducted to determine a method that could produce akara with a reduced frying time.

In order to microwave or steam the cowpea paste, there had to be a mold to set the shape of the akara. It was found that porcelain crucibles were suitable for both applications. Mini-muffin pans can be used in a steamer, and egg holders and small plastic sample cups were suitable for the microwave. The products made from these methods had very different shapes than traditional akara balls, but their flavor was similar to akara made from the original method.

Akara has a fat content of approximately 31% on a dry basis. The first trial using microwaving and steaming produced akara with about 26 and 27% fat, respectively. The microwaved samples were heated for 2 minutes on 1/2 power to set the shape. They were then fried for 45 seconds. The steamed samples were heated for 12-15 minutes and then fried for 45 seconds. These samples were lighter in color than the original akara and slightly lower in fat.

The second trial included freezing the sample before finish frying. These were prepared by either microwaving or steaming. Some samples were microwaved for 2-3 minutes on 1/2 power in small sample cups and some were steamed for 12-15 minutes in crucibles. The freezing step caused the samples to need more frying time, and even then still had cold spots in the center. Therefore, thawing was incorporated for samples to be analyzed. The samples were defrosted in the microwave for 1 min. and 25 s, then finish fried for 1 min and 15 s. Samples that were steamed and then fried had an average fat content of 44.2%; samples that were microwaved and fried had an average fat content of
43.8%. This was a great deal higher than traditional akara, so thawing provided another obstacle. The thawing step caused more water to be available for replacement with oil.

A third trial involved partially frying samples and then freezing them to be finish cooked in the microwave and/or conventional oven. Some were fried for 45 s and the remaining samples were fried for 60 s. The samples fried for 45 s and 60 s and then reheated in the conventional oven had a fat content of 27.2% and 29.2%, respectively. Samples fried for 45 s and 60 s and then reheated in the microwave had a fat content of 31.1% and 30.4%, respectively.

Another trial was conducted on the microwaving and steaming methods to see if the results were repeatable since there was a slight reduction in the fat content. However, it was discovered that how the samples were cooled made a difference in the fat content. It was necessary to cool the partially cooked samples out of the mold because that way excess moisture could evaporate. When the samples were cooled inside the containers, they retained moisture and therefore absorbed more fat during finish frying. Fat content of 26.3% was again obtained with samples that were microwaved for 2 minutes on 1/2 power and then fried for 45 s. These results suggest that a different cooking method is a possibility in reducing fat content of akara. A potential way to reduce the fat even more could be by the addition of modifiers such as gelatinized starch. Therefore, the first step for this research was to determine the effect that modifiers like starch had on the fat content of akara.

**Materials & Methods**

An all-white cultivar of cowpeas (California Cream) was provided by the Department of Botany and Plant Sciences, The University of California, Riverside.
Canola oil was purchased at Carden Foods in Griffin, GA. The bell peppers, onions, and salt were purchased at a local supermarket and the high amylose cornstarch (Hylon VII) was donated by National Starch & Chemical (Bridgewater, N.J.). The extruded cowpea flour was processed in the Department of Food Science and Technology, The University of Georgia, Athens, GA.

**Extruded Cowpea Flour Preparation**

The decorticated blackeye cowpea flour used to prepare the extruded flour was processed by the method described by McWatters and others (1993). The flour was extruded in a co-rotating twin screw extruder (model 1700-30, APV Baker, Newcastle-on-Tyne, England). A screw configuration comprised of conveying elements and both forwarding and reversing paddles was used in order to input significant mechanical energy into the dough. The moisture content was 23.4%. There were 5 temperature zones. The temperatures increased from 100 °C in zone 1 to 115 °C in zone 2 and then up to 135 °C in zones 3, 4 and 5. The temperature of the cooling water was 23 °C.

**Akara Preparation**

The akara prepared in this study was made from cowpeas having an all-white seed coat because an earlier study showed that akara made with this cultivar had a significantly lighter color than akara made from non-decorticated blackeyes (Patterson and others 2002). Using the California Cream cowpeas simplified paste preparation by not having to remove the seed coat as is customarily done in preparation of traditional West African akara using black-eyed peas. A 500 g batch size was used. The cowpeas were first soaked in cool tap water for 3 h to soften the seeds. They were then drained and ground using a Toledo chopper (model 5120-0-009, Toledo, Ohio, U.S.A.) in order
to reduce the particle size. For the control sample (64% paste moisture) and the sample with lower paste moisture (62%), the peas were immediately blended for 5 minutes in a Waring Blender (model 34BL22, New Hartford, Conn., U.S.A.). They were blended with the appropriate amount of water for 3.5 to 5 min; the blender was stopped every 30-45 s to scrape the sides of the blender jar. The formula to determine the appropriate amount of water to add for the target paste moisture content was:

\[
W_a = W_1(100-M_i)/(100-M_f) - W_s
\]

This formula is a modified version of the equation reported in McWatters and others (2001). Where \(W_s\) is the amount of water to be added to reach the target paste moisture, \(W_1\) is the initial weight of the dry peas, \(M_i\) is the initial moisture content of the peas, \(M_f\) is the target paste moisture content, and \(W_s\) is the weight of the soaked peas.

For the samples containing high amylose cornstarch or extruded cowpea flour, the flour or starch was added to the ground peas in the mixing bowl before blending in the blender. This enabled the modifiers to be incorporated into the peas without sticking to the blades of the blender. The amount of water to be added \((W_a)\) for the modified sample pastes was determined in a similar manner as the control, however, since neither the flour nor the starch were soaked, the weight of the dry flour or starch was added to the weight of the soaked peas \((W_s = \text{weight of soaked peas} + \text{weight of starch})\).

After blending, all samples were whipped for 1.5 min in a Hobart mixer (model N 50, Troy, Ohio, U.S.A.) on speed 3 to form the foam structure. After whipping, some of the paste was spooned into a U.S. standard dry measuring cup (1/4 cup, about 60 mL); the cup was tapped 10 times in order to remove excess air. The viscosity of whipped paste was then measured using a Brookfield viscometer (HATD model, Stoughton,
Mass., U.S.A.) equipped with the TC spindle and operated at 10 rpm. The specific gravity was also measured on duplicate samples of whipped paste spooned into a U.S. standard dry measuring cup (1/4 cup). The formula for calculating specific gravity was:

\[
\text{Specific Gravity} = \frac{\text{weight of filled container} - \text{weight of container}}{\text{volume of container}}
\]

Where volume of container = weight of container + boiled then cooled water - weight of container (Campbell and others 1979).

Once the specific gravity and viscosity measurements were made, 9.5% each of chopped bell pepper and chopped onion, and 1.5% salt were folded into the batter manually with a rubber spatula. A #40 ice cream scoop (approximately 20 mL) was then used to dispense the batter into hot (193 °C) oil. The balls were fried in a Belshaw continuous fryer (Belshaw Bros., Inc., Seattle, Wash., U.S.A.) for approximately 2 min ± 10 s, turning after 1 min, and then removed to drain on absorbent paper towels until cool. The samples were then packaged in labeled Ziploc® bags (S.C. Johnson & Son, Inc., Racine, Wis., U.S.A.) and refrigerated overnight until the sensory evaluation sessions were conducted the next day. When reheating samples for the sensory panels, extra samples were reheated for instrumental analysis. After cooling, instrumental texture and color measurements of akara balls were made; the remaining samples were frozen at -18C for proximate composition analysis at a later date.

**Proximate Composition**

The proximate composition of the finished product was determined. Samples were removed from the freezer and allowed to come to room temperature before grinding in a food chopper (model KSM-2B, Woburn, Mass., U.S.A.). The moisture content was determined on 5 g samples that were dried overnight (24 h) in a vacuum oven at 70 °C
under 25 mm Hg (modified AOAC method 925.09; AOAC 1995). The weight loss was calculated to determine the moisture content. Ash content was determined on 1 g samples using AOCS method Ba 5-49 (AOCS 1970). Dried samples remaining from moisture analysis were used for fat analysis. Fat analysis was determined by overnight solvent extraction (about 16-18 h) with petroleum ether using a Goldfisch apparatus (Labconco, Kansas City, Mo, U.S.A.). Nitrogen content was determined using the Dumas combustion method (LECO analyzer, model 602-600, Warrendale, Pa., U.S.A.) on the dry and defatted samples. A factor of 6.25 was used to convert nitrogen to protein content (FAO 1970).

**Instrumental Color and Texture Measurements**

The color and texture of akara were both measured instrumentally. One akara ball per consumer panel session (5 total sessions/day) was measured with a Minolta colorimeter (model CR-200, Osaka, Japan) calibrated with a brown reference tile (L*=69.82, a*=19.17, b*=31.75). Four locations on each ball were measured and all were averaged. Hue angles were calculated as arctan(b*/a*). The same akara balls used for color analysis were used for texture analysis. The texture was measured using an Instron universal testing machine (model 1122, Instron Corp., Canton, Mass., U.S.A.) equipped with a Kramer cell attached to a 500 kg load cell and operated at a crosshead speed of 50 mm/min and a chart speed of 100 mm/min. Peak force required to cut through the akara ball was determined and results are reported in newtons.

**Sensory Evaluation**

Forty untrained panelists participated in a two-day test. These panelists were recruited from a database maintained in the Department of Food Science and
Technology, Griffin, Ga. The panelists had to be at least 18 years of age, a regular consumer of fried foods, have no food allergies to the ingredients in the product, and be available for both test dates. Only four samples could be prepared daily, therefore, replications were prepared on alternate days (Monday and Wednesday). Panelists tasted four samples from the first replication (rep 1) on Tuesday and four from the second replication (rep 2) on Thursday. They rated each sample on a hedonic scale of 1 (dislike extremely) to 9 (like extremely) for the attributes of color, appearance, texture, aroma, flavor, and oiliness, and how they liked the sample overall. On the first day, the panelists completed a demographic questionnaire. On the second day, they filled out a questionnaire pertaining to their consumption of fried foods.

The akara needed to be served warm, therefore, samples were reheated from the refrigerated state in a conventional oven for 6 min at 204 °C and served in 2 ounce soufflé cups. Lemon water (concentration of 18 mL lemon juice to 1L water) and unsalted crackers were provided so that panelists could cleanse the palate between samples. The sample order was randomized and samples were served 5 min apart so that each panelist had adequate time to rate each attribute. Each panelist received a total of $20 for their participation in the 2-day study.

Statistical Analysis

Statistical analysis of proximate composition, sensory ratings, and instrumental measurements of color and texture was performed using ANOVA and LSD mean comparison test procedures of the Statistical Analysis System (SAS 1990).
Results & Discussion

Proximate Composition

The moisture content of akara containing either extruded cowpea flour or cornstarch was significantly higher (53.0% and 51.9%, respectively) than control akara (49.3%) or akara made from the lower moisture content paste without modifier (48.8%) (Table 3.1). With respect to fat content, all products were significantly different. Fat content was highest in the control (31%) and lowest (19.6%) in akara made with extruded cowpea flour. Akara containing 10% cornstarch had less protein (22.3%) than the other samples (24%). Ash content was highest (2.7 to 2.8%) in akara made from low moisture content paste or extruded cowpea flour and lowest (2.2%) in akara containing cornstarch.

Frying is a process that involves heat and mass transfer while a product is immersed in hot oil. It has been found that the higher the initial moisture content of the food, the more fat the food will absorb during frying (Gamble and Rice 1988) because the frying process involves migration of oil into the food and water into the oil simultaneously (Singh 1995). Therefore, lowering the moisture content of the paste initially could reduce the final fat content of akara because it would decrease the amount of water available to migrate. Also if a more hydrophilic ingredient were added to the batter, it would be more likely to retain water instead of absorbing oil while frying.

Starch molecules have the ability to increase functionality in foods. Some applications that starches are used for are binding, foam strengthening, gelling, and moisture retention (BeMiller and Whistler 1996). There are two main components of starch--amylose and amylopectin (Shih and Daigle 1999). Starch is added to fluids to increase their viscosities and this improves the water and fat holding abilities
Table 3.1. Proximate composition of akara prepared from various types of cowpea paste.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Akara proximate composition&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Paste moisture %</th>
<th>modifier</th>
<th>Moisture %</th>
<th>Fat&lt;sup&gt;b&lt;/sup&gt; %</th>
<th>Protein&lt;sup&gt;b&lt;/sup&gt; %</th>
<th>Ash %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>49.3c 31.0a 24.4a 2.4b</td>
<td>64</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LMC&lt;sup&gt;c&lt;/sup&gt;</td>
<td>48.8c 26.9b 24.2a 2.7a</td>
<td>62</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cornstarch</td>
<td>51.9b 22.9c 22.3b 2.2c</td>
<td>62</td>
<td>10% high amylose</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECPF&lt;sup&gt;d&lt;/sup&gt;</td>
<td>53.0a 19.6d 24.1a 2.8a</td>
<td>62</td>
<td>10% extruded cowpea flour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Values are an average of six measurements (two replications with three values each); values in a column not followed by the same letter are significantly different at alpha=0.05.

<sup>b</sup>Dry weight basis.

<sup>c</sup>This sample is a lower paste moisture content without a modifier.

<sup>d</sup>This sample contains extruded cowpea flour.
(Hermansson and Svegmark 1996). An earlier study by Shih and others (2001) used rice flour as the main component in a batter. According to these authors, the increased amylose content of the starch decreased oil uptake during frying. Therefore, a high amylose cornstarch was employed in this study.

Starches are usually modified in the food industry in order to increase the functionality. Pre-gelatinization is a modification used a great deal. The cowpea flour used in this study was extruded and, therefore, gelatinized. Extrusion is a process that uses high temperatures and high shear to cook a food product. It is used in production of many products, for example, modified starches, cereals, and snack foods (Harper 1978). Two important physico-chemical changes that occur during extrusion are protein denaturation and starch gelatinization.

Shih and others (2001) showed that doughnuts substituted with 50% gelatinized rice flour were comparable to all-wheat doughnuts in general characteristics but as much as 64% lower in oil uptake. Shih and Daigle (1999) also showed that batters made with gelatinized rice flour had significantly less oil uptake than those made with ungelatinized rice flour. Gelatinization has been known to increase cold-swelling, pasting properties (Jarowenko 1986), and water holding capacity. In our study, since cowpea is the main ingredient in akara, extruded cowpea flour was used as the gelatinized ingredient to evaluate its effectiveness in reducing the fat content of akara.

**Batter Properties and Instrumental Color and Texture Measurements**

The average foam viscosities for the control and cornstarch-containing samples were 89.7 and 112.6 Pa.s, respectively. Batters made with either lower paste moisture and no modifier or with the extruded cowpea flour were so viscous that the chart readings
were off-scale; these batters were visibly less "foamy" and heavier than the control or cornstarch batter. Even though the cornstarch sample also had 62% paste moisture content, the foam was less viscous and more like the control than the others. Specific gravity ranged from 0.702 to 0.877 (Table 3.2) with the control being the lowest and the sample containing extruded cowpea flour the highest. Specific gravity is a useful measure of the lightness of a foam. The greater the amount of air incorporated into a batter, the lower the specific gravity (Campbell and others 1979). We observed that the control exhibited better foam formation than batters made from extruded cowpea flour or the lower moisture paste without a modifier; the latter did not get enough air incorporated into the batters in order to form a good foam structure.

Akara made with extruded cowpea flour was darker ($L^*=44.1$), more red ($a^*=17.0$), less yellow ($b^*=30.1$), and had a lower hue angle (60.2) than the other samples (Table 3.2). The chroma (color intensity) values were not significantly different for any of the four samples and ranged from 34.3 to 35.9. Extrusion also causes what is known as the Maillard reaction. Due to high temperatures and low moisture content, reducing sugars react with free amino groups and cause browning (Berset 1989). This may explain why akara prepared with precooked extruded flour was darker than the other samples. Akara made from the extruded cowpea flour required less force to shear (315 N) than the other samples (373-404 N).

*Sensory Evaluation*

Of the 40 panelists, 25% were in the age bracket of 55-64 and 22.5% were ages 25-34. Most (85%) were female, white (80%), and had at least a high school degree (87%). Thirty five percent worked full time and 35% were retired. With regard to
Table 3.2. Specific gravity of batter and instrumental color and texture measurements of akara prepared from various types of cowpea pastes\(^a\).

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>LMC(^b)</th>
<th>Cornstarch</th>
<th>ECPF(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batter specific gravity</td>
<td>0.702c</td>
<td>0.761b</td>
<td>0.779b</td>
<td>0.877a</td>
</tr>
<tr>
<td>Hunter L(^d)</td>
<td>50.1a</td>
<td>50.0a</td>
<td>50.0a</td>
<td>44.1b</td>
</tr>
<tr>
<td>a*</td>
<td>13.5c</td>
<td>14.4b</td>
<td>14.3bc</td>
<td>17.0a</td>
</tr>
<tr>
<td>b*</td>
<td>31.4ab</td>
<td>32.8a</td>
<td>32.2a</td>
<td>30.1b</td>
</tr>
<tr>
<td>Hue angle</td>
<td>66.8a</td>
<td>66.1a</td>
<td>65.8a</td>
<td>60.2b</td>
</tr>
<tr>
<td>Shear force(^e)</td>
<td>373.5a</td>
<td>404.1a</td>
<td>381.5a</td>
<td>315.0b</td>
</tr>
</tbody>
</table>

\(^a\)Sample types are described in Table 1; values in a row not followed by the same letter are significantly different at \(\alpha=0.05\).

\(^b\)This is the lower paste moisture content sample without a modifier.

\(^c\)This sample contains extruded cowpea flour.

\(^d\)Hunter values are an average of four readings/ball. L* (lightness), +a* (redness), -a* (greenness), +b* (yellowness), and -b* (blueness); hue angle = \(\tan^{-1}(b*/a*)\).

\(^e\)Shear force is an average of 10 measurements and reported in newtons.
consumer acceptability (Table 3.3), all products were rated 6 (like slightly) for overall liking which indicates positive market potential for lower fat akara. There were no significant differences in the ratings of these products for any of the sensory attributes. This indicates that the panelists were not able to differentiate between samples. Oiliness was the only attribute to receive a mean rating below 6. Oiliness ratings ranged from 5.3-5.8 (neither like nor dislike). A few panelists commented that the product containing extruded cowpea flour was not completely cooked and needed to be cooked a little longer. This could explain the lower instrumental texture ratings of this sample.

The questionnaire that the panelists completed provided information on how well they liked this type of product, the form in which they would like to purchase it, how they would use the product, and whether the fat content would affect their overall acceptability of the product (Table 3.4). Most (80%) of the panelists liked this product at least moderately, with 30% liking it very much. Half said that the fat content would not affect their overall perception of acceptability and that they would rather have the full-fat version if it tasted better than the lower fat product. As to how they would use this product, 50% of the panelists said they would eat it as a side dish while 30% would use it as a bread product. About 67% said they would rather buy this product in the fully cooked form to be reheated at home instead of a partially cooked product to be finish fried at home. This is the same result that was found in an earlier study by Patterson and others (2002) on the preferred cultivar. This emphasizes the importance of convenience foods in consumers' lives, with 75% of the panelists indicating that they purchased convenience foods.
Table 3.3. Mean hedonic ratings for consumer acceptability of akara prepared with various types of cowpea pastes$^a$.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Control</th>
<th>LMC$^b$</th>
<th>Cornstarch</th>
<th>ECPF$^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>7.1</td>
<td>7.4</td>
<td>7.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Color</td>
<td>7.3</td>
<td>7.4</td>
<td>7.1</td>
<td>7.1</td>
</tr>
<tr>
<td>Aroma</td>
<td>6.5</td>
<td>6.6</td>
<td>6.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Flavor</td>
<td>6.3</td>
<td>6.5</td>
<td>6.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Texture</td>
<td>6.5</td>
<td>6.4</td>
<td>6.2</td>
<td>5.9</td>
</tr>
<tr>
<td>Oiliness</td>
<td>5.3</td>
<td>5.8</td>
<td>5.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Overall liking</td>
<td>6.3</td>
<td>6.5</td>
<td>6.3</td>
<td>6.2</td>
</tr>
</tbody>
</table>

$^a$Sample types are described in Table 1; means for sensory attributes are based on a 9-point hedonic scale with 1=dislike extremely and 9=like extremely. There were no significant differences at $\alpha=0.05$ for any attribute.

$^b$This sample is a lower paste moisture content without a modifier.

$^c$This sample contains extruded cowpea flour.
Table 3.4. Fried Product Questionnaire¹.

<table>
<thead>
<tr>
<th>Question</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How do you like the type of product you just evaluated?</td>
<td></td>
</tr>
<tr>
<td>Dislike very much</td>
<td>5.0</td>
</tr>
<tr>
<td>Dislike moderately</td>
<td>7.5</td>
</tr>
<tr>
<td>Neither like nor dislike</td>
<td>7.5</td>
</tr>
<tr>
<td>Like moderately</td>
<td>50.0</td>
</tr>
<tr>
<td>Like very much</td>
<td>30.0</td>
</tr>
<tr>
<td>2. How often do you eat fried foods?</td>
<td></td>
</tr>
<tr>
<td>Less than once a week</td>
<td>37.5</td>
</tr>
<tr>
<td>Once a week</td>
<td>15.0</td>
</tr>
<tr>
<td>Twice a week</td>
<td>35.0</td>
</tr>
<tr>
<td>Once a day</td>
<td>5.0</td>
</tr>
<tr>
<td>Twice a day</td>
<td>5.0</td>
</tr>
<tr>
<td>More than twice a day</td>
<td>2.5</td>
</tr>
<tr>
<td>3. Would the fat content affect your overall acceptability score?</td>
<td></td>
</tr>
<tr>
<td>For example, if one of these samples were lower in fat, would you</td>
<td></td>
</tr>
<tr>
<td>consider sacrificing texture or flavor quality to have the lower fat</td>
<td></td>
</tr>
<tr>
<td>version?</td>
<td></td>
</tr>
<tr>
<td>Yes, I would consider purchasing the lower fat version</td>
<td>45.0</td>
</tr>
<tr>
<td>No, I would rather have the full fat version if it tastes better</td>
<td>50.0</td>
</tr>
<tr>
<td>Not sure</td>
<td>5.0</td>
</tr>
<tr>
<td>4. Would you be willing to pay more for a reduced fat version of this</td>
<td></td>
</tr>
<tr>
<td>product than for the full fat version?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>17.5</td>
</tr>
<tr>
<td>No</td>
<td>55.0</td>
</tr>
<tr>
<td>Maybe</td>
<td>27.5</td>
</tr>
<tr>
<td>5. In what way would you most likely eat this type of product?</td>
<td></td>
</tr>
<tr>
<td>Snack food</td>
<td>2.5</td>
</tr>
<tr>
<td>Appetizer</td>
<td>15.0</td>
</tr>
<tr>
<td>Side Dish</td>
<td>50.0</td>
</tr>
<tr>
<td>Main Course</td>
<td>2.5</td>
</tr>
<tr>
<td>Bread</td>
<td>30.0</td>
</tr>
<tr>
<td>6. Would you rather purchase this product as a fully cooked, frozen</td>
<td></td>
</tr>
<tr>
<td>product to be reheated at home or would you prefer to finish fry this</td>
<td></td>
</tr>
<tr>
<td>product?</td>
<td></td>
</tr>
<tr>
<td>Frozen and reheated at home</td>
<td>67.5</td>
</tr>
<tr>
<td>Finish fry at home</td>
<td>32.5</td>
</tr>
</tbody>
</table>
Table 3.4 (continued).

<table>
<thead>
<tr>
<th>Question</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. How many would you consider a serving size?</td>
<td></td>
</tr>
<tr>
<td>One</td>
<td>7.5</td>
</tr>
<tr>
<td>Two</td>
<td>40.0</td>
</tr>
<tr>
<td>Three</td>
<td>35.0</td>
</tr>
<tr>
<td>More than three</td>
<td>17.5</td>
</tr>
<tr>
<td>8. How often do you order appetizers when you go out to eat?</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>17.5</td>
</tr>
<tr>
<td>Once in awhile</td>
<td>72.5</td>
</tr>
<tr>
<td>Usually</td>
<td>10.0</td>
</tr>
<tr>
<td>9. How important is convenience when buying food for your household?</td>
<td></td>
</tr>
<tr>
<td>Not important at all</td>
<td>10.0</td>
</tr>
<tr>
<td>Moderately important</td>
<td>45.0</td>
</tr>
<tr>
<td>Very important</td>
<td>45.0</td>
</tr>
<tr>
<td>10. Do you purchase convenience foods such as frozen dinners, meals in a box, rehydratable noodles, etc?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>75.0</td>
</tr>
<tr>
<td>No</td>
<td>25.0</td>
</tr>
<tr>
<td>11. If you answered yes to the above question, how often do you purchase convenience foods*?</td>
<td></td>
</tr>
<tr>
<td>Less than once a week</td>
<td>25.0</td>
</tr>
<tr>
<td>Once a week</td>
<td>20.0</td>
</tr>
<tr>
<td>Twice a week</td>
<td>20.0</td>
</tr>
<tr>
<td>Once a day</td>
<td>5.0</td>
</tr>
<tr>
<td>More than twice a day</td>
<td>5.0</td>
</tr>
</tbody>
</table>

\(^*\)n=40.  
*25% of the panelists said they did not purchase convenience foods, therefore did not answer this question.*
Conclusions

Results from this study indicate potential for the success of reduced-fat akara in the United States. The cornstarch (Hylon VII) and extruded cowpea flour were both successful in retaining considerable moisture in the final product. Akara batter containing these modifiers had a lower initial paste moisture content (62%) yet had a higher moisture content in the final product. The amylose in the starch most likely aided the starch's ability to retain moisture in the cooked product. It is known that amylose has good film-forming properties, and film-formation is a desirable characteristic when trying to reduce oil uptake (Balasubramaniam and others 1997; Nisperos-Carriedo 1994). The goal of this research was to reduce the fat content in akara by at least 25%, and both modifiers succeeded in doing so.

Akara has much potential for U.S. markets, given its nutritional advantages of being composed of cowpeas, a good source of protein, fiber and B-vitamins. We found that akara can be produced as a reduced fat product by the addition of modifiers while retaining the desirable sensory attributes of the traditional full-fat version. However, akara is still inconvenient and challenging to produce. Therefore, further research needs to be conducted to improve akara's marketability by increasing its ease of preparation. This could be done by determining the best freezing / storage method to simplify use by consumers and also by the foodservice industry. The foodservice sector in the U.S. uses a lot of freezer-to-fryer products; therefore, akara's likelihood to be adopted by this sector would be increased considerably if it can be made to utilize handling/ storing/ cooking practices already in place.
Acknowledgements

This research was supported by the Bean/Cowpea Collaborative Research Support Program, U.S. Agency for International Development (Grant # DAN-1310-G-SS-6008-00). The University of California at Riverside supplied the California Cream cultivar. Special thanks go to the following individuals for their technical assistance: Sandra Walker, Lary Hitchcock, Sue Ellen McCullough, and Richard Stinchcomb.

References


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SECTION IV

ENHANCED CONVENIENCE OF AKARA PREPARED WITH A TWO-STAGE FRYING PROCESS

Patterson, S.P., Phillips, R.D., Hung, Y.-C., Chinnan, M.S., and McWatters, K.H.
To be submitted to Foodservice Research International.
Abstract

Akara is a fried finger food that is very popular in West Africa. It has the potential to increase the consumption of cowpeas in the United States if made more convenient to prepare. Fried foods are very popular but tend to be consumed to a greater extent in foodservice settings than in the home. Therefore, if akara were made convenient for this use, its utilization could be increased. The samples in this study were initially cooked by frying and then fried a second time in order to either reheat or complete cooking. The three variables were pre- and post-cooking times (s) and starch level (%). Fat content of akara ranged from 31 to 41% and moisture content from 39 to 49%. Instrumental color measurements showed a darker product than samples from previous studies with L* values of about 37 to 47; texture measurements (peak force) ranged from 512 to 660 N. Crust thickness also increased with a second frying step. Internal temperatures were recorded on the partially cooked and the finish cooked samples. Temperatures ranged from 66.3°C to 96.3°C depending on the level of each variable. Cooking time had more of an effect on internal temperatures than did the starch level. The temperatures of the finish-fried samples showed a direct relationship with post-cooking time.

Keywords: Frying, Akara, Proximate composition, Foodservice industry.
**Introduction**

Fried foods are very popular in the United States--especially foods like french fries, potato chips, and fried chicken. Frying is a process that gives foods appealing sensory attributes such as aromas, flavors, and crispy textures. Most people do not want the hassle of frying at home because it is a very inconvenient process. Therefore, much of the fried food consumption is either from foods that are frozen and ready to reheat by conventional or microwave ovens or foods that can be purchased in a foodservice setting.

Because of the hectic schedules and busy lifestyles of today, people are eating out more and more. In 1999, about 1/2 of every dollar spent on food was on foods away from home (FAFH) and by 2010 it is expected to be even higher (Silver 1999; Sills-Levy 1989). Convenience is a big factor in meal purchasing. It has been stated that convenience is the most significant trend that will drive the food industry in the future (Sills-Levy 1989). Many of the foods that restaurants offer are fried, e.g., french fries, chicken fingers, onion rings, and cheese sticks.

Akara, a fried finger food made from cowpeas, is a very popular snack and/or breakfast food in West Africa. It offers a new way for the United States to increase the consumption of cowpeas. Cowpeas are very nutritious legumes that are underutilized in this country in part because of the time-consuming preparation processes of soaking and boiling.

Akara has been shown to be a very acceptable product to American consumers through various consumer tests in the Atlanta, Georgia area (McWatters et al. 1990; McWatters et al. 1992; Patterson et al. 2002a). Using an all-white cultivar (California Cream) provides a product that closely resembles the traditional West African product
and is devoid of the black specks associated with blackeyes. A study comparing the akara-making quality of three cowpea cultivars was conducted to determine if Americans preferred one cultivar over another; results showed that the cultivar did not affect the sensory scores with all samples being acceptable (Patterson et al. 2002a). The blackeye type is most often used for akara production in West Africa, but consumers do not like the dark color imparted by the black pigment and therefore decorticate the seeds to remove seed coats and blackeyes. By using California Cream, the decortication step is eliminated thus making the preparation process less time-consuming and more convenient.

Most of the research conducted with akara has been done on either freshly fried akara or akara that can be reheated by means of thawing and frying or simply by reheating in a conventional oven. The foodservice industry uses a great deal of batch frying. Much of the time batch frying is done by taking products directly from the freezer and immediately frying them from the frozen state without the thawing step. Many of these foods are individually quick frozen (IQF) whereby they are exposed to a freezing method that is much quicker than the conventional freezing method. Freezing causes the temperature of a food to fall below the freezing point and to form ice crystals (Fellows 1997). Freezing can cause several quality changes such as destabilization of an emulsion and/or textural changes as well as some changes in flavors and pigments. Quick freezing causes the formation of smaller ice crystals than in conventional freezing, and this causes less damage to cells (Fellows 1997). As for the frying oil temperature, the range of 163C-191C is normal for this industry (Banks 1996).
In this study, samples were partially or fully cooked, frozen, and finish cooked by frying without thawing to determine effects of a two-step frying process on product quality. The fat content is also important, therefore a high amylose cornstarch was added to selected samples. A previous study (Patterson et al. 2002b) showed a significant decrease in fat content of akara with a 10% addition of cornstarch. However, that study employed akara that was fried, frozen and reheated in a conventional oven.

**Materials and Methods**

California Cream cowpeas were used in this study. Canola oil was used as the frying medium and was purchased at a local supermarket along with green bell peppers, onions, and salt. Some samples used a high amylose cornstarch (Hylon VII) provided by National Starch and Chemical (Bridgewater, N.J.).

*Experimental Design*

A Box-Behnegen Design with a three-level design used to fit response surfaces was employed in this study (Montgomery 1991). The factors used were starch level (0, 5, and 10%), pre-frying time (60, 90, and 120 s), and finish frying time (4.75, 5.25, and 5.75 min). There were a total of 15 samples in the study, one of which was prepared in triplicate.

*Akara Preparation*

The same akara-making process was followed as in a previous study (Patterson et al. 2002b). The peas were soaked for 3 h to soften the seeds. They were then ground in a Toledo chopper (model 5120-0-009, Toledo, Ohio, U.S.A.) to reduce the particle size. The peas and/or the mixture of peas and starch were transferred to a Waring Blender (model 34BL22, New Hartford, Conn., U.S.A.) and blended for 3.5 to 5 min to blend
together the appropriate amount of water to reach the target paste moisture content. The moisture content of paste made with 0, 5, and 10% starch was 64, 63, and 62%, respectively. The samples with starch required less water and less blending time than those without starch. The paste was then whipped for 1.5 min in a Hobart Mixer (model N 50, Troy, Ohio, U.S.A.) in order to incorporate air into the batter. After whipping, the samples were dispensed with a #40 ice cream scoop (~ 20 ml) into hot (193°C) oil and partially fried in an electric skillet (model # 72062, West Bend Co., West Bend, Wis) for the selected time intervals.

After the samples were fried, the balls were cooled to room temperature for about 30-45 min and then quick frozen for 40 s using liquid nitrogen (Air Products and Chemicals, Inc., Columbus, Ga). Preliminary trials were conducted on freezing times to determine when the akara ball was frozen. Four balls at a time were immersed in liquid nitrogen with a stainless steel apparatus that enabled the handler to remove the balls from the liquid after 40 s. The frozen balls were then transferred to labeled ziploc® bags and stored at -18°C until finish fried 3 days later.

On the days of finish frying, samples were fried from the frozen state for the specified time intervals at 176°C (350°F). This temperature is commonly used for frying such foods as french fries and chicken fingers in foodservice settings (Orthoefoer et al. 1996). The finish fried akara balls were then cooled to room temperature. After cooling, 4 balls per sample type were subjected to instrumental texture analysis. The rest of the samples were frozen for later analyses.
**Instrumental Texture Measurements**

The Instron universal testing machine (model 1122, Canton, Mass.) was used to determine the peak force required to cut through the sample. The instrument was equipped with a Kramer cell attached to a 500 Kg load cell and operated at a crosshead speed of 50 mm/min. There were four readings per sample type and the results are reported in newtons. Weights of akara balls were also recorded.

**Proximate Composition**

Samples were removed from the freezer so as to warm to room temperature in the freezer bag. The samples were then ground in a food chopper (model KSM-2B, Woburn, Mass., U.S.A). The moisture content was determined using a modified AOAC method (925.09, AOAC 1995). Five-g samples were dried overnight in a vacuum oven at 70C under 25mm Hg. The weight loss was then calculated to determine the moisture content. The fat content was then determined using the dried samples. Fat analysis was determined by overnight extraction with petroleum ether using a Goldfisch apparatus (Labconco, Kansas City, Mo, U.S.A.). Nitrogen content of moisture-free, fat-free samples was determined using the Dumas combustion method (LECO analyzer, model 602-600, Warrendale, Penn., U.S.A.). A conversion factor of 6.25 was used to convert nitrogen content to protein content (FAO 1970).

**Instrumental Color Measurements**

The color of akara balls was determined using a Minolta colorimeter (model CR-200, Osaka, Japan) calibrated with a brown reference tile (L*=69.82, a*=19.17, b*=31.75). The samples had been finish-fried and frozen. They were then removed from the freezer and warmed to room temperature in the freezer bag before the color was
determined. Four balls per sample type and four locations on each ball were measured. Hue angles were calculated as arctan (b*/a*).

*Crust Thickness*

The crust thickness of the balls was determined using an Ultra Cal Mark III caliper (model # S 225, Fred V. Fowler Co., Inc., Newton, Mass). Three samples were cut open and three locations on each ball were measured for their crust thickness as accurately as possible.

*Internal Temperature Measurements*

The internal temperature of akara balls was measured for both the partially fried samples and the finish fried samples. The temperatures were measured using a T type thermocouple with a digital temperature display. The average size of the balls was measured to be approximately 30 mm. Therefore, the probe was marked at 15 mm to penetrate the center of the ball each time. The measurements were taken immediately after removing the balls from the hot oil. Readings were recorded every 15 s until the temperature stabilized and started to decrease. The peak temperature was recorded in degree Celsius.

*Statistical analysis*

The statistical analysis system (SAS Institute 1990) was used for analysis of the data. Response surface regression (PROC RSREG) was performed to determine the effect of the independent variables (starch level and cooking time) on the dependent variables (temperature, proximate composition, texture, color and crust thickness). Regression analysis was also performed (PROC REG) as well as LSD comparisons of the means at a significance level of $\alpha = 0.05$. 
Results and Discussion

Proximate Composition

Table 4.1 shows the significance of the model equations used for the contour plots of the responses. Table 4.2 shows the proximate composition of each sample. The fat content of akara in previous studies (Patterson et al. 2002a,b) was approximately 31% on a dry basis. Lowering the fat content was accomplished by the addition of modifiers like starch and gelatinized cowpea flour (Patterson et al. 2002b). However, these samples were either freshly fried or reheated in a conventional oven. This is not very convenient for foodservice establishments since they use batch frying. In this research, a two-step frying process was used in order to determine the effect two frying steps had on the fat content and if the addition of starch kept the fat content lower than other samples without starch.

The pre-cooking variable showed little effect on fat content (Figure 4.1 A,B,C). There was a slight increase in fat content with an increase in pre-cooking time, but only between 60 and 90 s cooking. These contour plots show that at the shortest cooking time (285 s), starch had little effect on the fat content of akara. At 345 s, however, fat decreased as starch increased. At 0% starch, increasing the cooking time increased the fat content. At 10% starch, cooking had little effect on the fat content. The fat content of the samples in this study, which ranged from approximately 31 to 41% fat on a dry-weight basis, was higher than that of samples in previous studies which ranged from 30 to 32% (Patterson et al. 2002a,b). The samples with 10% starch contained less fat than samples made without starch.
Table 4.1. Analysis of variance table of the effects of variables on the linear, quadratic and interaction terms on the responses.

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of Freedom</th>
<th>Crust Thickness</th>
<th>Fat Content</th>
<th>Moisture Content</th>
<th>L* (lightness)</th>
<th>Texture</th>
<th>Pre-temperature</th>
<th>Post-temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>9</td>
<td>10.15***</td>
<td>290.45***</td>
<td>277.52***</td>
<td>1653.53***</td>
<td>173813.00*</td>
<td>6751.03***</td>
<td>2991.38***</td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>4.75</td>
<td>246.17***</td>
<td>188.97***</td>
<td>1022.77***</td>
<td>50062.00</td>
<td>6684.36***</td>
<td>2697.88***</td>
</tr>
<tr>
<td>Quadratic</td>
<td>3</td>
<td>2.99**</td>
<td>16.58***</td>
<td>16.71**</td>
<td>98.96</td>
<td>38999.00</td>
<td>59.68*</td>
<td>217.13**</td>
</tr>
<tr>
<td>Interaction</td>
<td>3</td>
<td>2.41*</td>
<td>27.70***</td>
<td>71.83***</td>
<td>531.80***</td>
<td>84751.00**</td>
<td>6.99</td>
<td>76.37</td>
</tr>
</tbody>
</table>

*** = significant at 1% level.
** = significant at 5% level.
* = significant at 10% level.
Table 4.2. Proximate composition of twice-fried akara prepared from different treatments.\(^a\)

<table>
<thead>
<tr>
<th>Starch %</th>
<th>Pre-cooking time (s)</th>
<th>Post-cooking time (s)</th>
<th>Moisture (%)</th>
<th>Fat (%)(^b)</th>
<th>Protein (%)(^b)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>60</td>
<td>315</td>
<td>38.89 ± 0.25</td>
<td>37.56 ± 0.29</td>
<td>24.66 ± 0.06</td>
<td>2.22 ± 0.07</td>
</tr>
<tr>
<td>0</td>
<td>90</td>
<td>285</td>
<td>44.55 ± 0.29</td>
<td>38.21 ± 0.37</td>
<td>24.10 ± 0.03</td>
<td>2.71 ± 0.02</td>
</tr>
<tr>
<td>0</td>
<td>90</td>
<td>345</td>
<td>38.69 ± 0.37</td>
<td>40.14 ± 0.38</td>
<td>25.20 ± 0.10</td>
<td>2.44 ± 0.06</td>
</tr>
<tr>
<td>0</td>
<td>120</td>
<td>315</td>
<td>43.00 ± 0.16</td>
<td>41.21 ± 0.40</td>
<td>24.15 ± 0.08</td>
<td>2.39 ± 0.02</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>285</td>
<td>43.99 ± 0.19</td>
<td>35.34 ± 0.18</td>
<td>23.25 ± 0.09</td>
<td>2.41 ± 0.11</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>345</td>
<td>43.51 ± 0.18</td>
<td>34.19 ± 0.19</td>
<td>23.33 ± 0.03</td>
<td>2.80 ± 0.04</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>315</td>
<td>43.69 ± 1.79</td>
<td>36.44 ± 1.38</td>
<td>23.02 ± 0.65</td>
<td>2.47 ± 0.12</td>
</tr>
<tr>
<td>5</td>
<td>120</td>
<td>285</td>
<td>45.65 ± 0.14</td>
<td>37.49 ± 0.55</td>
<td>22.73 ± 0.09</td>
<td>2.32 ± 0.02</td>
</tr>
<tr>
<td>5</td>
<td>120</td>
<td>345</td>
<td>46.15 ± 0.14</td>
<td>38.18 ± 0.17</td>
<td>22.46 ± 0.01</td>
<td>2.57 ± 0.03</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>315</td>
<td>47.27 ± 0.22</td>
<td>30.62 ± 0.20</td>
<td>22.24 ± 0.22</td>
<td>1.81 ± 0.06</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>285</td>
<td>43.18 ± 0.34</td>
<td>37.31 ± 0.71</td>
<td>21.83 ± 0.14</td>
<td>2.40 ± 0.02</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>345</td>
<td>46.61 ± 0.29</td>
<td>33.52 ± 0.28</td>
<td>21.90 ± 0.12</td>
<td>2.41 ± 0.01</td>
</tr>
<tr>
<td>10</td>
<td>120</td>
<td>315</td>
<td>48.37 ± 0.28</td>
<td>33.19 ± 0.19</td>
<td>21.13 ± 0.09</td>
<td>2.47 ± 0.03</td>
</tr>
</tbody>
</table>

\(^a\)All are averages of three readings per sample.
\(^b\)These are on a dry-weight basis.
**Figure 4.1:** Contour plots of fat content of akara with varying pre-cooking times ($X_2$) of (A) 60 s, (B) 90 s, and (C) 120 s.

**Model:**

\[
\text{Fat} = 96.7304 + 2.4419X_1 + 0.232487X_2 - 0.483743X_3 - 0.001X_2^2 \\
- 0.009536X_3X_1 + 0.000828X_3^2
\]

\[R^2 = 0.8700\]

$X_1 = \text{starch level (\%)}$, $X_2 = \text{pre-cooking time (s)}$, $X_3 = \text{post-cooking time (s)}$
The results for moisture content show interaction between post-cooking time and starch level but little effect due to pre-cooking time (Figure 4.2 A,B,C). As post-cooking time increased, the moisture content of akara decreased. This makes sense considering that frying is a dehydration process. The contour plots indicate that moisture content increased as starch increased. However, starch level had less effect than the post-cooking variable. At 10% starch addition, moisture content increased with an increase in post-cooking time. At 0% starch addition, moisture content decreased with an increase in the cooking time. This shows that starch has the ability to retain water in the product and could provide a way to keep the fat content of akara in the range of freshly fried akara, however, starch level interacts with post-cooking time and the moisture content depends on the levels of both variables. The moisture content is lower in these samples than in the previous study where moisture ranged from 48 to 50%.

**Instrumental Texture Measurements**

Table 4.3 shows instrumental texture, color and crust thickness data for each sample. In Figure 4.3 starch content was plotted against post-cooking time in contour plots to determine the effect of these variables on texture (peak force) of akara. Pre-cooking time was not included in this model because this variable was not significant independently or with its interaction terms. Post-cooking time had the most effect on the texture of akara at the 0% starch level where a steady increase in peak force values was shown. However, the samples with 10% starch showed a slight decrease in cutting force with an increase in cooking time. This same type of relationship was shown with the starch content variable. At the lowest cooking time (285 s), cutting force increased with an increase in starch. However, with the longest cooking time, there was a decrease in
Figure 4.2: Contour plots of moisture content of akara with varying pre-cooking times ($X_2$) of (A) 60 s, (B) 90 s, and (C) 120 s.

Model:

\[
\text{Moisture} = 73.39982 - 3.911462X_1 - 0.17114X_2 - 0.088059X_3 
- 0.005X_2X_1 + 0.001315X_2^2 + 0.015466X_3X_1
\]

$R^2 = .8417$

$X_1 = \text{starch level (\%)}, \quad X_2 = \text{pre-cooking time (s)}, \quad X_3 = \text{post-cooking time (s)}$
Table 4.3. Instrumental texture (peak force), color, and crust thickness measurements for akara prepared from different treatments.

<table>
<thead>
<tr>
<th>Starch %</th>
<th>Pre-cooking time (s)</th>
<th>Post-cooking time (s)</th>
<th>Peak force&lt;sup&gt;a&lt;/sup&gt; (N)</th>
<th>L*&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Hue angle&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Crust thickness&lt;sup&gt;c&lt;/sup&gt; (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>60</td>
<td>315</td>
<td>575.60 ± 36.76</td>
<td>39.19 ± 5.91</td>
<td>56.89 ± 5.00</td>
<td>2.79 ± 0.45</td>
</tr>
<tr>
<td>0</td>
<td>90</td>
<td>285</td>
<td>518.89 ± 62.75</td>
<td>44.51 ± 5.70</td>
<td>62.14 ± 4.33</td>
<td>2.32 ± 0.30</td>
</tr>
<tr>
<td>0</td>
<td>90</td>
<td>345</td>
<td>660.53 ± 111.74</td>
<td>39.10 ± 4.15</td>
<td>57.01 ± 4.11</td>
<td>3.46 ± 0.53</td>
</tr>
<tr>
<td>0</td>
<td>120</td>
<td>315</td>
<td>608.66 ± 165.10</td>
<td>41.78 ± 5.17</td>
<td>58.79 ± 5.31</td>
<td>2.39 ± 0.43</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>285</td>
<td>461.51 ± 63.99</td>
<td>47.26 ± 5.45</td>
<td>63.97 ± 4.55</td>
<td>2.43 ± 0.42</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>345</td>
<td>542.81 ± 87.80</td>
<td>37.48 ± 3.30</td>
<td>55.36 ± 2.43</td>
<td>2.92 ± 0.60</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>315</td>
<td>519.51 ± 109.03</td>
<td>41.41 ± 5.68</td>
<td>58.55 ± 5.01</td>
<td>2.72 ± 0.66</td>
</tr>
<tr>
<td>5</td>
<td>120</td>
<td>285</td>
<td>433.27 ± 32.98</td>
<td>45.66 ± 4.84</td>
<td>62.13 ± 4.68</td>
<td>2.68 ± 0.55</td>
</tr>
<tr>
<td>5</td>
<td>120</td>
<td>345</td>
<td>570.59 ± 111.15</td>
<td>41.27 ± 6.44</td>
<td>58.35 ± 5.95</td>
<td>2.53 ± 0.49</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>315</td>
<td>512.63 ± 79.96</td>
<td>47.11 ± 6.21</td>
<td>63.07 ± 4.83</td>
<td>2.62 ± 0.38</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>285</td>
<td>618.68 ± 53.95</td>
<td>42.94 ± 5.64</td>
<td>60.27 ± 4.74</td>
<td>2.76 ± 0.71</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>345</td>
<td>457.21 ± 38.92</td>
<td>45.91 ± 6.96</td>
<td>62.14 ± 6.04</td>
<td>3.09 ± 0.80</td>
</tr>
<tr>
<td>10</td>
<td>120</td>
<td>315</td>
<td>512.21 ± 138.62</td>
<td>43.88 ± 5.60</td>
<td>60.84 ± 5.34</td>
<td>2.23 ± 0.30</td>
</tr>
</tbody>
</table>

<sup>a</sup>Peak force values are an average of 3-4 readings per sample.

<sup>b</sup>L* (lightness) and hue angle values are an average of 16 readings (4 readings per sample, 4 samples per type).

<sup>c</sup>Crust thickness values are an average of 9 readings per sample.
Figure 4.3: Contour plot of instrumental texture measurements of akara holding pre-cooking time ($X_2$) at 60 s.

Model:

$$ \text{Texture} = -441.898285 + 131.30046 \times X_1 + 3.278788 \times X_3 + 1.89816 \times X_1^2 - 0.497595 \times X_3 \times X_1 $$

$$ R^2 = .2696 $$

$X_1 = $ starch level (%), $X_2 = $ pre-cooking time (s), $X_3 = $ post-cooking time (s)
force with an increase in starch. This suggests interaction between post-cooking time and starch level. It was observed that immediately after frying, the samples seemed very hard. Compared to previous samples that were fried only once, these samples were a great deal tougher.

Previous studies (Patterson et al. 2002a,b) show akara with texture measurements of approximately 375 to 415 n. This study showed samples with higher measurements. However, after cooling and as the texture measurements were being conducted, the samples seemed much softer than they were straight from the fryer. A better test may be to use a puncture test immediately after frying for both the samples fried only once and the twice-fried samples. Weights of akara balls in this study ranged from 16.5 g to 20.7 g.

**Instrumental Color Measurements**

Akara from the previous study (Patterson et al. 2002b) had a lightness (L*) value of 50 for the control sample and for akara containing starch. The sample containing extruded cowpea flour had a lower L* value of 44 indicating a darker product. These samples from the previous study were rated acceptable with respect to color, receiving sensory scores of 7.1 to 7.3 on a 9-point hedonic scale.

The average L* values for the samples in this study ranged from 37.5 to 47.3, indicating that they were darker than those fried only once. However, some were as dark or lighter than the sample containing extruded cowpea flour in the previous study depending on the level of each independent variable.

Figure 4.4 shows the contour plots of the L* value for the samples in this study. The cooking times (pre and post) were plotted against each other while starch was held
Figure 4.4: Contour plots of L* (lightness) values varying starch level. (A) X1=0%, (B) X1=5%, (C) X1=10%,

Model:

\[
L^* = 121.929518 - 3.1396X_1 - 0.415143X_2 - 0.27333X_3 \\
- 0.0097X_2X_1 + 0.013954X_3X_1 + 0.001493X_3X_2
\]

\[R^2 = .1724\]

\(X_1 = \text{starch level (})\), \(X_2 = \text{pre-cooking time (s)}\), \(X_3 = \text{post-cooking time (s)}\)
constant at 0, 5, and 10% (Figure 4.4 A,B,C respectively). As shown in the contour plots, there were interactions between variables. When starch level increased, the L* value also increased, suggesting that a lighter product can be obtained by the addition of starch.

When holding starch level as the constant variable, there is interaction between the cooking time variables. With 0% starch, pre-cooking did not affect the L* value (Figure 4.4A). However, with 10% starch, the longer the sample was cooked, the darker the product (Figure 4.4C). Post-cooking time and starch level had a greater effect on L* values than pre-cooking time.

**Crust Thickness**

The thickness of the crust of the twice-cooked samples was higher than that of the samples used in our previous studies (Patterson et al. 2002a,b) which were fried only once and then reheated in a conventional oven. The crust thickness of samples fried only once was in the range of 1.08 to 1.93 mm. Results from the present study showed that the twice-fried samples had a crust thickness ranging from 1.80 to 4.03 mm (averages 2.2 to 2.5 mm). This measurement was very difficult to obtain because the crust layer was not easy to distinguish or separate from the crumb. This could have led to readings that were not very consistent. Visually, the samples that were fried twice had a more flaky crust than those fried only once. Handling these samples caused a great deal of crumbs to accumulate on the paper towels where they were draining.

The effect of the three variables on crust thickness is not clear-cut. The contour plots in Figure 4.5 illustrate that interactions between each variable were significant. Again, both pre and post cooking times were plotted against each other while holding starch level constant at 0, 5, and 10%. The post-cooking time seemed to have the
**Figure 4.5:** Contour plots of crust thickness (mm) varying starch level.
(A) $X_1 = 0\%$, (B) $X_1 = 5\%$, (C) $X_1 = 10\%$.

**Model:**

Crust thickness = $19.73 + 0.41X_1 + 0.104X_2 - 0.96X_3$
- $0.00027X_2^2 - 0.0008X_3X_1 - 0.00012X_3X_2$
+ $0.00012X_3^2$

$R^2 = 0.1889$

$X_1$ = starch level ($\%$), $X_2$ = pre-cooking time (s), $X_3$ = post-cooking time (s)
greatest effect on crust thickness since as the post-cooking time increased, so did crust thickness. Starch content and pre-cooking time showed a smaller effect than post-cooking time on the dependent variable.

*Internal temperature measurements*

Studies on internal temperatures of akara have not been conducted in the past. These measurements could provide useful information to determine if factors like cooking time and/or starch content have an effect on the internal temperature of akara. This could also be helpful if the temperature could predict if the sample is cooked.

Internal temperatures of the partially fried akara were recorded. In Figure 4.6, starch is plotted against pre-cooking time in order to determine the contour plots of the temperatures. This figure shows that pre-cooking time had the most effect on temperature. As expected, internal temperature increased as cooking time increased. The starch content, however, had a smaller effect than cooking time on the internal temperature, showing an inverse relationship with internal temperature.

As for the internal temperatures of the finish-fried product, Figure 4.7 shows the contour plots when pre-cooking times are plotted against post-cooking times. The three levels of starch addition are all shown as the constant variable in order to demonstrate how little starch affected the temperature. This emphasizes that cooking time was the primary influence on internal temperature. As the post-cooking time increased from 4.75 min to 5.75 min, the temperature showed a steady increase up to a point where the temperature then started to stabilize. As the pre-cooking time increased, a small decrease was shown, but it did not affect the internal temperature to the extent of post-cooking time.
Figure 4.6: Contour plot of the effect of starch level (X1) and pre-cooking time (X2) on the temperature (C) of the partially cooked akara samples.

Model:

\[ \text{Pre-temp} = -39.094034 + 0.078583*X_1 + 0.402506*X_2 + 0.506086*X_3 - 0.031888*X_1^2 - 0.00082*X_3^2 \]

\[ R^2 = .9002 \]

X₁ = starch level (%), X₂ = pre-cooking time (s), X₃ = post-cooking time (s)
Figure 4.7: Contour plots of the internal temperatures (°C) of finish-fried akara balls holding starch level ($X_1$) constant; (A) 0%, (B) 5%, and (C) 10%.

Model:

$$\text{Post-temp} = -224.460259 + 0.36699*X_1 - 0.06698*X_2 + 1.782168*X_3 - 0.086596*X_1^2 - 0.002454*X_3^2$$

$$R^2 = .6188$$

$X_1 =$ starch level (%), $X_2 =$ pre-cooking time (s), $X_3 =$ post-cooking time(s)
Samples were periodically cut open to determine if they were cooked all the way through. The samples were considered completely cooked when the interior crumb had a bready interior that was similar to that of the previous studies (Patterson et al. 2002a,b). Some samples were partially cooked, and therefore the interior was sometimes not set and had a creamy interior that was not bready. The samples that were fried for 5.25 min and 5.75 min were completely cooked and not dependent on pre-cooking time. However, the post-cooking time of 4.75 min produced some samples that were not completely cooked. The samples that were partially cooked for 60 or 90 s sometimes had an incompletely cooked center. When observing the temperatures recorded for these samples, they did not reach as high a temperature as most samples. Internal temperatures of 68.6ºC and 67.3ºC were recorded for the samples that were not completely cooked in the center. If temperature is a measurement that can predict if an akara ball is cooked, results from this experiment indicate that the internal temperature needs to reach at least 70-72ºC to be cooked throughout.

**Conclusions**

Results from this study indicate that akara may have the potential to comply with current cooking practices employed by the foodservice industry since finish frying at a common oil temperature of 176ºC is possible. This would increase the convenience of this product even more by providing another venue for akara's consumption besides home use. The product can be partially cooked, frozen, and reheated/finish cooked by frying. The samples were darker and tougher than the samples that were fried only once, but this does not conclude that they will be considered unacceptable. Sensory evaluation of twice-cooked samples is needed to determine their acceptability. The variables that had
the most effect on the physical characteristics of akara were post-cooking time and starch level.

The results do show that the fat content of twice-fried samples without starch was higher than that of freshly fried samples, but with a starch level of 10%, fat content was maintained at approximately the same percentage as in previous studies. Added starch also had a small effect on color lightness of the cooked product. Samples with 10% starch had an L* value close to that of akara made with 10% extruded cowpea flour in a previous study (Patterson et al. 2002b). The color of those samples was considered by sensory panelists to be acceptable. Samples formulated with 10% starch could provide a way to make akara more marketable for the foodservice industry by increasing the convenience while also maintaining the fat content at a level normally associated with traditional akara.

**Acknowledgements**

This research was supported by the Bean/Cowpea Collaborative Research Support Program, U.S. Agency for International Development. The University of California at Riverside supplied the California Cream cultivar. Special thanks go to the following individuals for their technical assistance: Sandra Walker, Lary Hitchcock, Richard Stinchcomb, Glen Farrell, and Sue Ellen McCullough.
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SECTION V

SUMMARY AND CONCLUSIONS
Many consumer sensory evaluation panels have proved that Akara is an acceptable product to American consumers. Since cowpeas are such an important source of nutrients, akara provides a new way to consume the legume. The first section of this thesis found that cultivar did not affect the acceptability of akara with all three cultivars evaluated producing highly acceptable end products.

The first objective of this research was to lower the fat content of akara because it is a deep-fat fried food that is very high in fat. In order to make this product more marketable, modifiers were added to evaluate their effect on the fat content. The fat content was lowered significantly by about 26% with a high-amylose starch and by about 36% with the addition of extruded cowpea flour. Consumer panels determined that these samples were acceptable. These results show great potential in marketing akara in a reduced fat version. The targeted market for this version is mainly for home use because people do not like the inconvenience of frying foods at home.

Eating foods away from home is on the rise today. Convenience is a big factor in most everyone’s lives because of the more hectic schedules seen today. Since fried foods are so popular in the American culture, akara could be targeted to the foodservice industry. Therefore, the other objective of this research was to make akara more convenient for the foodservice sector by structuring it as a freezer-to-batch fryer product.

Physical measurements showed that the freezer-to-fryer product was darker, tougher and had a thicker crust than previous samples. The fat content of these samples ranged from 31-41%, which is higher than that of “control” akara (31%). However, adding 10% starch maintained the fat at approximately the same level as traditional akara. This shows potential for marketing akara to the foodservice industry.
Results from these studies indicate that akara does have the potential to provide a new way to increase the consumption of cowpeas in the United States. Since the akara-making process is very tedious and time-consuming, its inconvenience makes it an impractical food to make from scratch. Akara has been shown to be very acceptable as a pre-fried frozen product that is easily reheatable in a conventional oven. This makes home use a good area to target when marketing akara. Results also indicate the possibility of marketing this product to the foodservice industry. This would increase the consumption of cowpeas as well as giving Americans a novel food product that West Africans have enjoyed for years.