Effect of Soybean and Melon Seed Flour Supplementation in Cocoyam and Wateryam Flour Blends Used for Ekpang Nkukwo

Rosemary Collins Piate, Ph.D, Etebong Gabriel Udobong & Mary Nelson Okorie
Department of Home Economics Education
Akwa Ibom State College of Education, Afaha Nsit, Nigeria
Corresponding Email: bankross@gmail.com

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Abstract
This study examined the functional properties of Ekpang Nkukwo, a traditional Nigerian dish made from cooked cocoyam and wateryam, supplemented with soybean or melon flours at varying levels (10%, 15%, and 20%). In this research, various proportions of soybean and melon seed flours were supplemented in cocoyam and wateryam flours to assess their effects on the functional properties, including bulk density, gelation capacity, emulsion stability, water absorption capacity, foam stability, and foam capacity. Bulk density of the flour blends ranged from 0.60 to 0.84 g/ml, with higher supplementation levels resulting in decreased bulk density. Soybean blends exhibited higher gelation capacity (8-12%) compared to melon flour blends. Emulsion stability varied from 11.20 to 21.40 ml/g, with melon flour blends showing lower values. Water absorption capacity decreased as flour supplementation increased, ranging from 1.60 to 3.00 ml/g. Foam stability ranged from 62.81% to 89.13%, with soybean blends displaying higher stability. Foam capacity increased with higher flour supplementation but decreased over time. Overall, soybean flour supplementation yielded better functional properties compared to melon flour blends, with significant differences observed among the blends. Based on these findings, the researchers recommended that food scientists, nutritionists, agriculturists, policymakers and product developers should provide training and extension services to agriculturists, establish and enforce food safety standards and regulations, launch consumer awareness campaigns to educate the public and advocate for supportive policies and incentives at the governmental level to promote the cultivation of nutrient-rich varieties of cocoyam, wateryam, soybean, and melon seeds using sustainable agricultural practices.

Keywords: *Ekpang Nkukwo, Soybean, Melon Seeds, Functional Properties, Wateryam, Flour Supplementation, Sensory Acceptance.*

Introduction

Dietary patterns and food choices are pivotal factors influencing human health and nutrition (Nanbol & Namo, 2019). The increasing awareness of the health advantages associated with varied and well-balanced diets has sparked a growing curiosity in investigating alternative food sources and inventive food compositions. Root and tuber crops, such as cocoyam (Colocasia esculenta) and wateryam (Dioscorea alata), are essential components in the diets of numerous regions globally, notably in sub-Saharan Africa, Asia, and the Caribbean

(Matikiti, 2017; Ojo et al., 2022). These crops serve as substantial sources of dietary carbohydrates, vitamins, and minerals, thereby bolstering food security and nutrition, as discussed by Taylor (2018) within the Araceae family according to Okpala (2013).

Cocoyam is the third most significant root and tuber crop in Nigeria, following yam and cassava. However, its consumption is often associated with low-income segments of society in certain communities, primarily due to its widespread availability at a relatively affordable price, as noted by Olayiwola et al. (2013) and James et al. (2013). Despite this perception, cocoyam stands out for its superior nutritional value compared to other root and tuber crops, as highlighted by Ojinnaka and Nnorom (2015). It boasts a higher content of crude protein and its starch exhibits excellent digestibility owing to the small size of its starch granules, as discussed by Ojo et al. (2022). Furthermore, cocoyam is rich in calcium, phosphorus, vitamin A, and B-vitamins, according to Kabuo et al. (2018). Despite its nutritional prowess, cocoyam remains underutilized in Nigeria, with its utilization predominantly at subsistence levels, rendering it a highly neglected crop, as emphasized by Amadi (2017). In the South Eastern region of Nigeria, cocoyam flour finds widespread use as a soup thickener, as noted by Ojo et al. (2022). Additionally, studies have shown that cocoyam exerts a beneficial effect on lowering blood glucose levels, indicating its potential as an anti-hyperglycemic agent and recommending its inclusion in the diets of diabetic individuals, as highlighted by Folasire et al. (2016). Recognizing the nutritional and chemical compositions of cocoyam, it is evident that its full exploitation could significantly enhance food and nutrition security for tropical populations, as indicated by the Food and Agriculture Organization (FAO, 2006).

However, despite their nutritional significance, cocoyam and wateryam are underutilized and encounter various challenges that hinder their widespread adoption and consumption. Promoting the acceptance of supplemented Ekpang Nkukwo among consumers necessitates educational campaigns and awareness efforts to underscore its nutritional advantages and address potential resistance to altering dietary habits. Protein deficiency remains a notable issue in numerous regions worldwide, particularly in areas where root and tuber crops serve as dietary staples (Bawa, 2023). As stated by Iwe (2003), soybean proteins constitute approximately 40% of the total solids and play a crucial role in food processing. Akobundu et al. (1982) revealed that melon seeds contain 28.4% protein, 2.7% fiber, 3.6% ash, 57.0% fat, and 8.2% carbohydrate. Melon, belonging to the *Curcubitae family*, is both nutritious and economically significant as a global source of biodiesel (Giwa & Akanbi, 2020; Manta et al., 2021). Originating from West and Central Africa, melon is akin to watermelon and belongs to the same family as the cantaloupe variety of melon seeds utilized in this study (Anees et al., 2021; Li et al., 2023).

Soybean stands out as an economical and abundant source of plant protein capable of addressing the nutritional requirements of millions of individuals. Apart from its protein content, soybean seeds are recognized for possessing the highest nutritional value among all plant foods consumed globally (Peter-Ikechukwu et al., 2019). Soybeans typically contain protein (35-45%), oil (15-25%), and approximately 33% carbohydrates, with around 16.6% being soluble sugars (Hou et al., 2009). Additionally, they boast approximately 19.10% ether extract, 5.71% crude fiber, 5.06% mineral content, and 26.05% nitrogen-free extract (Ogundele et al., 2015). Glycine max, commonly known as soybean, is a leguminous plant cultivated extensively for its edible seeds, which offer a remarkable nutritional and functional food profile (Peter-Ikechukwu et al., 2019). With a nutrient composition that underscores its nutritional value, soy-based foods are widely regarded as nutritious and beneficial for health. Notably, soybeans are the sole plant source containing all essential amino acids, with a higher protein content compared to other legumes. Moreover, soy protein is renowned for its quality and ease of digestion. Rich in fat, soybeans primarily comprise unsaturated fatty acids, with polyunsaturated (mainly linoleic acid), monounsaturated (oleic acid), and saturated (primarily palmitic acid) fatty acids constituting approximately 63%, 23%, and 14%, respectively. Soybeans also boast a significant polyunsaturated fat content, including alpha-linolenic acid, an essential omega-3 fatty acid. Furthermore, soybeans are replete with essential nutrients such as B-vitamins, calcium, iron, and phosphorus, along with antioxidants and phytonutrients like phytosterols and phytoestrogens, associated with various health benefits (Peter-Ikechukwu et al., 2019).

To address the challenges of enhancing the protein content and quality of cocoyam and wateryam-based foods, researchers have turned to the supplementation of cocoyam and wateryam flours with protein-rich ingredients such as soybean and melon seed flour. Soybean and melon seed are recognized for their high protein content, essential amino acid profile, and functional attributes, contributing to enhancement of nutritional and functional properties of cocoyam and wateryam-based food products (Falade & Okafor, 2014). By incorporating these supplementary flours into cocoyam and wateryam flour blends, the resulting composite flours will exhibit improved functional properties such as solubility, water absorption capacity, viscosity, and textural characteristics (Matikiti, 2017). The functional properties of soybean and melon seed flour supplementation in cocoyam and wateryam flours play a crucial role in determining their suitability for various food processing applications such as "Ekpang Nkukwo". Ekpang Nkukwo, a traditional Nigerian for the people of Akwa lbom and Cross River States dish, exemplifies a rich culinary tradition, comprising mashed (*Colocasia esculenta*) and wateryam (*Dioscorea alata*) (Ani et al., 2012). It is a hearty and nutritious one-pot meal made from cocoyam and wateryam, grated and blended into a smooth paste, then mixed with a flavorful combination of palm oil, spices, and sometimes crayfish. The mixture is wrapped in fluted pumpkin leaves (*Telfairia occidentalis*) and steamed until cooked through, resulting in a dense and slightly gelatinous texture (Enwere, 1998).

Ekpang Nkukwo is often enjoyed as a main course, served alongside protein-rich accompaniments such as fish or meat, and is cherished for its rich taste, cultural significance, and ability to bring people together in communal celebrations and gatherings. By harnessing the potential benefits of soybean and melon seed flour supplementation in cocoyam and wateryam flour blends and fostering interdisciplinary collaborations between food scientists, nutritionists, agriculturists, and policymakers, this study seeks to examine the effect of soybean and melon seed flour supplementation on the functional properties of cocoyam and wateryam flour blends. Ultimately, the findings of this research have the potential to inform evidence-based strategies for enhancing dietary diversity, nutritional adequacy, and food sustainability, thereby contributing to improved health outcomes and well-being for communities globally.

MATERIALS AND METHODS

Material Procurement

Freshly harvested matured cocoyam (*Colocasia esculenta)* and wateryam (*Dioscorea alata)* tubers were purchased from Uyo central market in Akwa Ibom State and transported to Makurdi in polyethylene bags. Soybean variety (TGX1485-ID) was obtained from the National

Cereals Research Institute (N.C.R.I) Yandev, Sub-station, Gboko Local Government Area, Benue State. Melon seeds was purchased from Modern Market, Makurdi.

Methodology

Preparation of cocoyam mash

Five kilograms of cocoyam tubers were washed in water to remove dirt. The tubers were weighed, manually peeled with the aid of a stainless-steel knife, sliced into thickness of about 1.0 -1.5 cm and then washed with clean potable water. The sliced cocoyam of about 0.8cm thick was blanched at 90 ˚C for 3 minutes before grating.

Production of Soybean Flour

Five kilograms of soybean seeds was dried cleaned by winnowing and then washed with clean water free from foreign materials such as stones and leaves were boiled for 30 minutes. The seeds were then soaked in water for 4h. The seed coat was removed by rubbing the soaked seeds between the palms of the hands. The decorticated seeds were dried in cabinet dryer at 55 ˚C until properly dried. The dried soybean seeds were ground using electrically powered blender into flour. The resultant flour was sieved to a particle size of 500m and packed in polyethylene bags (Akpapunam, 2004).

Preparation of melon flour

Five kilograms of manually dehulled kernels were blanched by putting them in a plastic basket and exposing them to saturated steam of 90-95oC for 5 minutes. The blanched melon kernels were dried in an oven at 60oC for 9 hours. The dried melon kernels were ground using electrically powered blender into flour. The resultant flour was sieved to a particle size of 500m and packaged in polyethylene bags (Chinma, 2005).

Preparation of Ekpang Nkukwo

Beginning with the gathering of the main ingredients, cocoyam and water yam the process involves meticulous peeling, grating, and pounding to create a smooth paste. This paste is then mixed with ingredients like crayfish, palm oil, and assorted spices, infusing the dish with rich flavors. The mixture is carefully wrapped in fluted pumpkin leaves (*Telfairia occidentalis*), creating parcels that are steamed to perfection. The resulting dish is a harmonious blend of textures and tastes, embodying the essence of Nigerian heritage and culinary artistry. Fig 1 and figure 1 shows the formulation and flow chart of cocoyam, wateryam, soybeans and melon seeds for the preparation of "Ekpang Nkukwo" dish

SN	Cocoyam Mash (g)	Wateryam Mash (g)	Soybean Flour (g)	Melon Flour (g)
1.	70	30	-	-
2.	65	30	5	-
3.	65	30	-	5
4.	60	30	10	-
5.	60	30	-	10
6.	55	30	15	-
7.	55	30	-	15
8.	50	30	20	-
9.	50	30	-	20

Table 1 The formulation of cocoyam, wateryam, soybeans and melon seeds

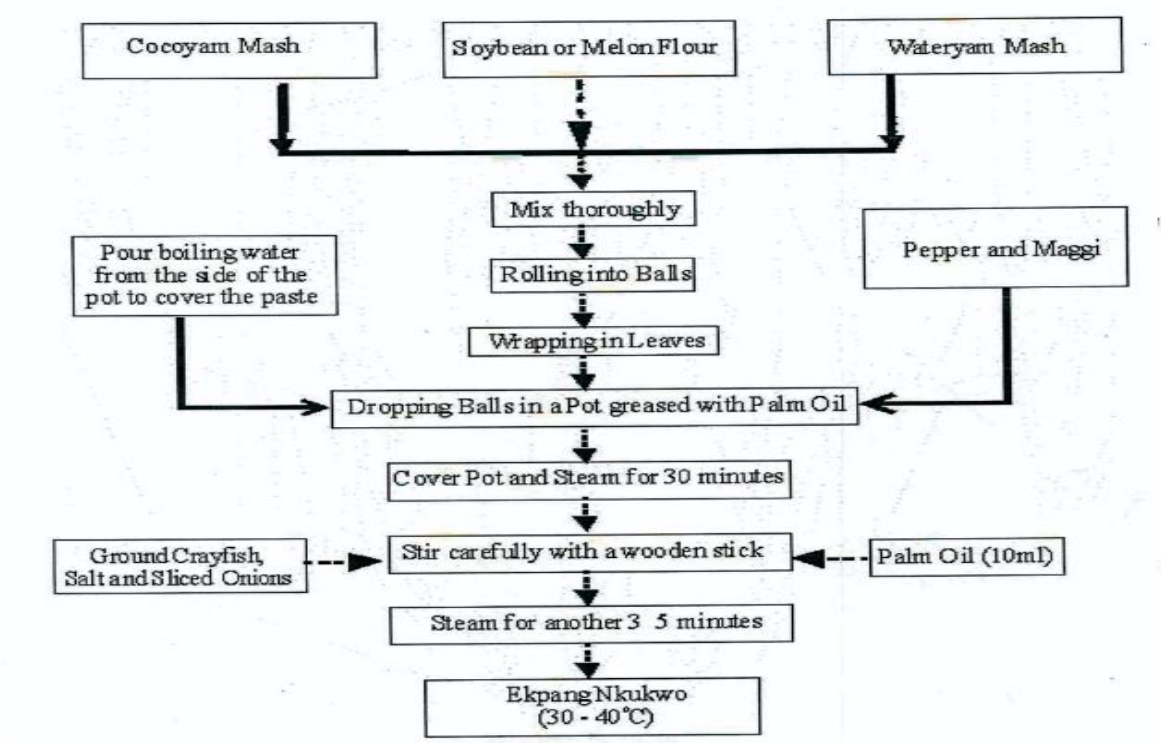

Figure 1: Flow chart for the preparation of "Ekpang Nkukwo" dish

RESULTS AND DISCUSSION

Functional Properties of Cocoyam and Wateryam

Table 3 shows the effect of soybean and melon flour supplement on the functional properties of Cocoyam and wateryam.

Keys:

CW	=	70g Cocoyam flour: 30g Wateryam flour
CW_5	=	65g Cocoyam flour: 30g Wateryam flour: 5g Soybean flour
CW_{10}	=	60g Cocoyam flour: 30g Wateryam flour: 10g Soybean flour
CW_{15}	=	55g Cocoyam flour: 30g Wateryam flour: 15g Soybean flour
CW_{20}	=	50g Cocoyam flour: 30g Wateryam flour: 20g Soybean flour
CW_5	=	65g Cocoyam flour: 30g Wateryam flour: 5g Melon flour
CW_{10}	=	60g Cocoyam flour: 30g Wateryam flour: 10g Melon flour
CW_{15}	=	55g Cocoyam flour: 30g Wateryam flour: 15g Melon flour
CW_{20}	=	50g Cocoyam flour: 30g Wateryam flour: 20g Melon flour
LSD	=	Least Significant Difference

Sample Code	Bulk Density g/ml	Gelation Capacity %	Foam Capacity ml/g			Foam stability %	Emulsion Stability ml/g	Water Absorption Capacity ml/g	Oil Absorption Capacity ml/g
			0^{1}	30^{1}	60^{1}				
CW	$0.84^{a} \pm 0.01$	8	$46^{g} \pm 0.81$	$44^{g} \pm 0.81$	$41^{d} \pm 0.81$	$89.13^{a} \pm 0.19$	$11.20^{f} \pm 0.15$	$2.97^{b} \pm 0.04$	$3.00^{a} \pm 0.08$
CWS_{5}	$0.75^{c} \pm 0.01$	12	$49^{f} \pm 0.81$	$46^{ef} \pm 0.81$	$43^{c} \pm 0.81$	$87.75^{b} \pm 0.20$	$14.36^{e} \pm 0.12$	$2.56^{c} \pm 0.04$	$1.00^{b} \pm 0.08$
CWS_{10}	$0.70^{de} \pm 0.01$	12	$54^{e} \pm 0.81$	$49^{d} \pm 0.81$	$45^{b} \pm 0.81$	$83.33^{c} \pm 0.25$	$18.13^{c} \pm 0.12$	$2.05^{d} \pm 0.04$	$0.60^{c} \pm 0.08$
CWS_{15}	$0.62^{f} \pm 0.01$	12	$64^{b} \pm 0.81$	$57^{b} \pm 0.81$	$49^{a} \pm 0.81$	$76.56^{d} \pm 0.29$	$19.66^{b} \pm 0.12$	$1.80^{f} \pm 0.04$	$0.40^{b} \pm 0.00$
CWS_{20}	$0.60^{f} \pm 0.01$	12	$67^{a} \pm 0.81$	$59^{a} \pm 0.81$	$50^{a} \pm 0.81$	$74.62^{e} \pm 1.39$	$21.40^{a} \pm 0.08$	$1.80^{f} \pm 0.00$	$0.40^{b} \pm 0.08$
CWM_{5}	$0.81^{b} \pm 0.01$	10	$48^{f} \pm 0.81$	$45^{fg} \pm 0.81$	$33^{g} \pm 0.81$	$68.75^{f} \pm 0.53$	$12.05^{f} \pm 0.04$	$3.00^{a} \pm 0.00$	$0.63^{c} \pm 0.04$
CWM_{10}	$0.71^{d} \pm 0.01$	10	$53^{e} \pm 0.81$	$46^{ef} \pm 0.81$	$34^{g} \pm 0.81$	$64.15^{g} \pm 0.56$	$15.60^{de} \pm 0.16$	$2.00^{e} \pm 0.04$	$0.40^{d} \pm 0.08$
CWM_{15}	$0.68^{dc} \pm 0.01$	10	$59.16^{d} \pm 1.02$	$47^{e} \pm 0.81$	$37.16^{f} \pm 1.02$	$62.81^{h} \pm 0.64$	$17.00^{cd} \pm 0.01$	$1.80^{f} \pm 0.04$	$0.23^{e} \pm 0.04$
CWM_{20}	$0.64^{f} \pm 0.01$	10	$62^{c} \pm 0.81$	$50^{c} \pm 0.81$	$39^{e} \pm 0.81$	$62.90^{h} \pm 0.48$	$20.00^{ab} \pm 0.08$	$1.60^{f} \pm 0.04$	$0.20^{e} \pm 0.00$
LSD	0.04	-	1.68	1.70	1.68	0.88	1.44	0.02	0.13

Table 1: Effect of soybean and melon flour supplement on the functional properties of Cocoyam and wateryam

The result of functional analysis of flour blends shown in table 1, revealed significant differences in colour/appearance, texture and flavour from blends of "Ekpang Nkukwo". Bulk density obtained decreased with increasing level of soybean or melon flour supplementation. According to Iwe (2003), bulk density is affected by starch content of the sample. The study showed that when soybean protein is added to food systems, bulk density is reduced. Furthermore, the study showed, the lower the bulk density value, the higher the amount of flour particle that can stay together thus increasing the energy contents that could be derivable from such formulations and in the same vein, it would appear that increase in fat content might reduce bulk density as particles of flour blends containing high fats appeared to have agglomerated thus forming larger particles (Okaka & Isiah, 1990). The low bulk density of the flours will be an advantage in the preparation of wearing food formulation and packaging.

According to Hermanson (1979) gelation is due to the aggregation of denatured molecules involving the formation of a continuous network which exhibit a certain degree of order. The low gelling values of cocoyam; water yam flour blend compared to soybean and melon flours could be attributed to low concentration of molecules of good gelling power in the flour. This property will make such composite blends very useful in food systems which require thickening and gelling such as "Ekpang Nkukwo". Foam capacity in the blends increased with increasing level of soybean or melon flour supplementation. The blend also produced stable foams (foam stability). This increase in such properties in the blends may be attributed to the increasing protein content (Iwe, 2003) which is desirable in "Ekpang Nkukwo".

The study revealed that emulsion stability varies with type, concentration and stability of protein in flour. The result of this research showed that such variations were related to the concentration of soybean and melon flours protein in the blends. The result of this research is in line with earlier studies of Akubor et al. (2000) and Achi (1999) who reported that the higher the concentration of proteins in the food flour, the higher the emulsion stability and activity. Onimawo and Onojim (2003) reported a value of 49.00ml/g for 80:20 (sorghum; soybean) flour blend which is higher than 21.40ml/g obtained in this research for 50:30:20 (cocoyam, water yam, and soybean) and 20.00ml/g for 50:30:20 (cocoyam, water yam, melon) flour blends. This variation may be due to high protein content of sorghum glow when compared to cocoyam and water yam flours as well as processing treatment given to sorghum flour. Water and oil absorption capacity of the flour blends were affected by increasing level of soybean or melon flour supplementation. water and oil absorption are known to be affected by both proteins concentrating and the conformational characteristics of proteins (Iwe, 2003, Sathe & Salunkle, 1982). Achi (1999) reported a decrease in water absorption capacity of yam; soybean flour blends with increasing level of soybean flour.

CONCLUSION

The present study investigated the effect of soybean and melon seed flour supplementation on the functional properties of "Ekpang Nkukwo" obtained from composite mixture made up of cocoyam and wateryam flour blends, aiming to enhance the nutritional quality and techno-functional characteristics of these composite flours for diverse food applications. The functional properties of cocoyam and wateryam highlight their significance in various culinary applications and food processing. Cocoyam, known for its starchy consistency, exhibits excellent water absorption capacity, swelling ability, and viscosity when cooked, making it suitable for thickening agents and dough formulations. Wateryam, on the other hand, possesses similar properties but with a higher water content, contributing to its softer texture and smoother mouthfeel when incorporated into dishes. Both cocoyam and wateryam contribute to the textural integrity, stability, and palatability of food products, emphasizing their role as versatile ingredients in traditional and modern cuisine. Understanding and leveraging these functional properties are essential for optimizing the utilization of cocoyam and wateryam in food processing and culinary practices.

The findings of this study demonstrated that the addition of soybean and melon seed flours significantly influenced the functional properties of cocoyam and wateryam flour blends. Specifically, supplementation with soybean and melon seed flours led to improvements in bulk density, gelation capacity, emulsion stability, water absorption capacity, foam stability, and foam capacity. These enhancements are attributed to the protein-rich nature of soybean and melon seed flours, which contribute to the formation of a network structure within the flour blends, thereby improving their water-binding and gel-forming properties. The findings from this research have practical implications for the food industry, especially in the development of nutritious and functional food products tailored to meet the needs of diverse consumer populations which could serve as a basis for the formulation of innovative food products offering improved sensory attributes and nutritional value.

Recommendations

To enhance the functional properties of Cocoyam and Wateryam flour blends supplemented with soybean or melon flours, the researchers recommend that food scientists, nutritionists, agriculturists, policymakers and product developers should:

1. Provide training and extension services to agriculturists to promote the cultivation of nutrient-rich varieties of cocoyam, wateryam, soybean, and melon seeds using sustainable agricultural practices.
2. Develop innovative processing techniques to effectively incorporate soybean and melon seed flour into cocoyam and wateryam flour blends, ensuring optimal nutrient retention and enhancing the sensory attributes of Ekpang Nkukwo.

3. Establish and enforce food safety standards and regulations governing the production, processing, and distribution of supplemented Ekpang Nkukwo to ensure consumer safety and product quality.
4. Launch consumer awareness campaigns to educate the public about the nutritional benefits of consuming supplemented Ekpang Nkukwo as part of a balanced diet, fostering increased demand for the product.
5. Facilitate market access for producers of supplemented Ekpang Nkukwo by providing market information, facilitating linkages with retailers and distributors, and exploring export opportunities to reach wider markets.
6. Advocate for supportive policies and incentives at the governmental level to promote the production, marketing, and consumption of supplemented Ekpang Nkukwo, thereby contributing to improved nutrition and food security at the community level.

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