

DEVELOPING CULTURALLY ACCEPTABLE PEANUT NUTRITION BARS WITH  
SMALLHOLDER WOMEN FARMERS IN KAFFRINE, SENEGAL

by

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DEDICATION

To my family, for taking me as I am, whoever I am.

I love you guys, especially you grandma.

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## CHAPTER ONE

### DEVELOPING CULTURALLY ACCEPTABLE PEANUT NUTRITION BARS WITH SMALLHOLDER WOMEN FARMERS IN KAFFRINE, SENEGAL USING PARTICIPATORY ACTION RESEARCH

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**Abstract**

Smallholder farming families in Senegal suffer from poverty with children deficient in micronutrients despite contributing 80% of food exported and consumed in Senegal. The aim of this study is to employ participatory action research to seek out hindrances with value-added processing and recommendations to develop a culturally acceptable and nutritious product for school-age children in partnership with smallholder women farmers in Kaffrine, Senegal.

A survey was conducted with 60 smallholder farmers in the Diamal, Ndangane, Keur serigne djibel and Ngouye Siwakh communities to identify constraints to peanut farming and value-added processing. Interested male and female survey participants were invited to focus group discussions to provide depth to survey findings and develop ideas for a healthy peanut product.

The survey and focus groups revealed quality seeds, farm input and income as the challenges to peanut farming and food security and access to mills and other post-harvest equipment, as community needs. The focus groups identified Quakers Peanut Butter Baked Squares as a reference for peanut product due to its similarity to local peanut cakes and selected corn flour, cowpea flour and baobab powder as healthy ingredients.

From the surveys, all four communities were generally interested in value-added processing, and the women farmers identified as responsible for processing the harvest. The women were therefore selected to evaluate developed prototypes, which they found to have an acceptable taste but crumbly texture.

## **Introduction**

Smallholder farmers do not share in the wealth obtained from either exportation of peanuts or the manufacture of peanut oil. Poverty rates have barely declined from 46.7% in 2015, and about 57.1% of food insecure households are headed by smallholder farmers (USAID, 2015). Senegal ranks as the 9<sup>th</sup> largest exporter of peanuts globally, which contributes over USD 22 million to the country's foreign exchange (Fofana et al., 2018). Smallholder farmers are mostly responsible for the production of peanuts in Senegal and accounted for 250,000 tonnes of peanuts produced in a single year (Georges et al., 2016). Processing companies purchase peanuts from smallholder farmers at USD 0.33 per kg and sell the finished peanut oil for about USD 2 per kg (Slette & Aradhey, 2016). Exporting over 80,000 tons of peanut oil, the local processing companies gross over USD 45 million in export revenue (Georges et al., 2016).

Bountifield International, a non-profit organization, collaborated with smallholder farmers to improve the quality of harvested peanuts and reduced postharvest losses. Bountifield develops and provides labor-saving equipment such as lifters for harvesting peanuts, and postharvest technology such as multi-crop grinders and aflatoxin test kits to smallholder communities (Technology, 2013). Smallholder farmers are involved in the equipment design and testing which produces affordable, manually-operated farm equipment and allows continued use with little maintenance needed (Appropriate Technology, 2013). Bountifield's appropriate farm technology allows smallholder farmers the time and the resources to engage in off-farm activities, which add value to their peanuts.

The resources provided by Bountifield, creates opportunities for smallholder farmers to develop value-added peanut products, which can potentially rescue farmers from the low-income levels and deliver micronutrients to children. When the value-added peanut product is made ready-to-eat and nutritionally balanced, it can also support households to efficiently provide healthy diet for children. Developing interventions and products to support indigenous communities however has experienced discontinuity and in some cases absolute failure when western scientific methods are used (Simonds & Christopher, 2013). Success and sustainability of intervention is mostly observed when the indigenous community participates in the research process (Simonds & Christopher, 2013). Research models that capture the knowledge of participants and encourage interaction with the target community are utilized to foster partnerships with participants (Shamrova & Cummings, 2017).

Participatory Action Research as a research model places emphasis on communication with the target community and the development of culturally centered research designs (Méndez et al., 2017). surveys and focus group discussions were therefore employed in the PAR approach (Méndez et al., 2017; Shamrova & Cummings, 2017) to identify and establish a common understanding of challenges and dialogue with participants to find a feasible solution. The objective of this study is therefore to collaborate with smallholder peanut farmers in Kaffrine Senegal via participatory action research to gather their needs, interests, recommendations and feedback on developing a culturally acceptable, nutritious, value-added peanut product.

Using a PAR approach will give the farmers and the community a sense of ownership of the product and internal commitment to the research (Méndez et al., 2017). The PAR process will implant the culture and food preferences of the people in the development of the product, resulting in co-created knowledge (Méndez et al., 2017), which will enhance product acceptance and continuity of production within the communities. The product ingredients and recipe formulated will be based on the resources available to the community and focus on addressing the identified dietary and health challenges of the community. The study therefore offers an opportunity for the smallholder farmers to improve the community's nutrition security while profiting from the value-added products.

### **Using participatory action research in community food product development**

Value-added processing has been identified by both researchers and the government of Senegal as a means of improving farmers' income in the rural sector (Georges et al., 2016). Value added processing has the potential to unveil innovative peanut products and reduce the sale of peanuts by smallholder farmers to middle men and processing companies (Brethenoux et al., 2011; Program, 2018). Innovative peanut products created from studies to improve value-added processing in Senegal realized a significant acceptance by the public from conducted sensory tests (De Groote et al., 2018). Such studies however partner with local scientists, government agencies and small and medium sized enterprises with smallholder farmers having minimal involvement in the product design and creation (De Groote et al., 2018; Mohammed, 2007).

The continued limitation of commercial value added processing in rural communities calls for the involvement of smallholder farmers in efforts to develop innovative products from peanuts. Participatory action research has been used successfully in rural communities to instigate social change and development through partnership with community members (Jull et al., 2017; Mapfumo et al., 2013). Participatory action research has proved to be particularly effective with farming communities and has been adapted in studies to improve farming methods and activities (Méndez et al., 2017). The PAR approach of prefection, research, reflection and action with community members allows the establishment of relationships between the research team and the community members and an authentic commitment to community development (Méndez et al., 2017).

Participatory action research utilizes both quantitative and qualitative data collection tools to gather information on the prevailing situation and available resources in the community to solve the problem (Shamrova & Cummings, 2017). Surveys and focus group discussions, which are also applied in food product development (Mied & Bruseberg, 2000), are therefore utilized to understand the needs of the community and develop local solutions (Méndez et al., 2017; Shamrova & Cummings, 2017). Focus group discussions employed in the food industry involves consumers evaluating new products to gauge potential markets(Speight et al., 2019). The PAR approach will engage smallholder farmers in focus groups to identify local resources and feasible mechanisms for product development. Constant communication with the community members even after product development evaluates feasibility into the local context and identifies areas for further improvement (Méndez et al., 2017).

## **Methods and procedures**

### **Study site**

Senegal ranks as the 9<sup>th</sup> largest exporter of peanuts globally with peanuts contributing over \$22 million in foreign exchange (Fofana et al., 2018). The peanut sector occupies 70% of the population with the major cultivation areas being Kaolack, Fatick, Kaffrine, Diourbel and Louga (Fig. 1.1.) which form the peanut basin (Georges et al., 2016).

The study was conducted in four communities occupied predominantly by peanut farmers, Diamal, Ndangane, Keur serigne djibel and Ngouye siwakh, in the Kaffrine region. Small-scale, rain-fed agriculture is the main occupation in the four communities with peanuts being the most cultivated crop. Peanut production is mainly undertaken by the men who own land and have access to donkeys, ploughs and other farm implements while the women are more involved in processing the harvest into peanut oil and paste (Elizabeth et al., 2015).

The farmers however suffer from low income levels due to the high cost of seeds and the low prices of peanuts purchased by oil processing companies after harvest (Slette & Aradhey, 2016). Women farmers sell harvested peanuts in the form of peanut paste, roasted peanuts and other semi-processed products (Georges et al., 2016) at low prices due to questionable quality and safety. Partnerships between the women and Bountifield International, a non-profit organization, has improved the yield and quality of harvested peanuts as well as expanded the options of post-harvest value added processing (Technology, 2013).



**Fig. 1.1:** Location of the study site, peanut basin of Senegal (source: SRI-RICE, Cornell University)

## **Methods**

This study utilized a Participatory Action Research model (PAR) with both quantitative and qualitative methods to collect information from smallholder farmers. The use of both quantitative and qualitative methods provides an avenue for triangulation and validation of findings through cross-comparison (Salite, 2019). Participatory Action Research (PAR) was the choice approach for working with the communities due to its ability to instigate social change with feasible methods, interventions and the involvement of the entire

community or disadvantaged social groups within (Mapfumo et al., 2013). PAR processes presents the knowledge and expertise of the target population, in this case smallholder women farmers and leads to the creation of an active partnership with the research team (Méndez et al., 2017).

The study was conducted between June 2019 before the rainy season and January 2020 after harvest to ensure farmers were available to participate in the study. Semi-structured surveys with smallholder farmers were conducted in the four communities with help from Bountifield International to gain a grasp of the needs of smallholder farmers, value-added processing and demography. Trained staff from Bountifield International interviewed smallholder farmers who were willing to take the survey and recorded their responses using the doForms data collection software (Zendesk Inc, Dublin, Ireland). The surveys were also used to select participants and develop topics for the focus group discussion based on answers regarding interests in value-added processing. A question on the most challenging problem in the community was inquired from participants as recommended (Sowell et al., 1999) in the holistic process of community development. The survey was conducted in wolof and responses were transcribed in French into coded survey questionnaire with permission from the participants. The survey recruited 24 men farmers and 24 women farmers. Descriptive statistics with Microsoft XLSTAT (Addinsoft Inc, New York, New York) was used to present the survey data.

Focus group interviews were conducted in each of the four communities with participants of the survey who expressed interest in being part of the research process. Farmers who were present at the time of the discussion and were willing were also included in the study.

A semi-structured discussion guide was used to conduct the discussion (Jervis & Drake, 2014). The focus group discussion was conducted in Wolof (Senegalese local language) and was translated into English with the help of a translator. Each focus group session was audiotaped with permission from the participants and typed into a transcript after crosschecking information with participants.

One women's and one men's focus group per community, a total of eight focus groups of around eight to ten participants per group were formed (Salite, 2019). Communities like Ndangane and Ngouye Siwakh however had more than ten participants present. Participants were grouped according to gender to make them feel less constrained during discussions and to generate more data (Salite, 2019). Separating focus groups according to gender also allowed investigation of in-depth similarities and differences in participant's opinions. The chief and the sanitation officer were however present for the women's focus group discussion with the sanitation officer acting as the women's group secretary.

The focus group discussions explored participants' opinions on peanut farming; value added processing and healthy foods development for school-age children. Value-added peanut products including Quaker Peanut Butter Baked Squares (Quaker, Salem, New Jersey), PB2 powdered peanut butter (PB2foods, Tifton, Georgia) and Skippy P.B. Bites (Harmel foods, Austin, Minnesota), and Noflaye (Senegalese peanut flour) were presented to the focus groups for sampling to stimulate ideas for a value-added product.

A coding scheme was developed for transcripts from focus group discussions to organize, classify and compare data according to similarities. Nvivo 12 (QSR, Melbourne, Australia)

was used to create themes from the codes to enable analysis of data. Themes were used to obtain a clear distinction of topics and opinions generated during discussions and to group similar ideas together.

A semi-structured post survey was conducted after the focus group discussion to assess the participants' satisfaction with the PAR process (Méndez et al., 2017) as well as test out prototype peanut products created from the collaboration. The post survey targeted the participants of focus group discussions but the prototype evaluation relied on the women's leaders in all four communities to provide an assessment. Questionnaires were therefore applied to 65 participants of the focus group discussions and four women's leaders were asked to assess the prototype.

A final focus group discussion was conducted with smallholder women farmers in three of the four communities. The purpose of the discussion was to demonstrate the process of baking the developed peanut cake and to assess the acceptance of the product and baking process by the women. The focus group discussion also touched on the total cost of production, product name, potential market prices and a name for the product.

## Results

### Needs of smallholder farmers and problems in the community

During the FGDs and in the surveys conducted, smallholder farmers were asked about the problems with peanut farming, ways to improve peanut farming and the biggest problem in the community. The responses showed that the greatest farming problems was farming input, especially concerning quality seed access and fertilizer (Table 1.1). The lack of farming tools and post-harvest processing equipment were also regarded as impediments to improving farm incomes and community development. Male farmers were more concerned and vocal on topics related to farming and farm income whilst women were more concerned about post-harvest processing.

The male farmers considered the limited access to quality peanut seeds as the foremost impediment to a good crop yield. Comments such as “*We don't have good seeds. The seeds we have, the rain is too short for it to finish its cycle,*” emphasized the male farmers' issues with poor growing seeds. Farmers acknowledged receipt of quality peanut seeds by the government however the quantities received are never enough for their plots of land. The central government controls peanut seeds in Senegal (Tankari, 2012), however the centralization of agricultural institutions in urban areas restrict the effective distribution of peanut seeds especially to rural areas. The farmers attributed their growing of various crops in place of peanuts as a cash crop to the limited quantity of quality seeds.

The lack of quality seeds contributes to the identification of fertilizer as a means of improving farming and farming outcomes by the farmers. Responses such as “*farming is*

*difficult because the soil has low fertility*” and *“the soil fertility is very low, but no money to buy fertilizer”* emphasize the frustration of using low-yielding seeds for farming. The desire for synthetic chemicals for crop farming is also driven by insect attack (which plagues the farmers before and after harvest. *“Yes, but insecticides are too expensive. If I can afford them, I would use any that can work to get rid of the insects”* responded the chief of Ngouye siwakh to the problem of insect attack.

Simple labor-saving farming tools like seeding machines and milling machines were regarded as community needs and were highlighted in the discussions on ways to improve peanut farming. *“The animals will work for only one hour and be exhausted. Seeding machines will be important support.”* Smallholder farmers in sub-Saharan Africa strongly utilize physical labor in farm activities, which limits production and makes farming unappealing to the youth (Appropriate Technology, 2013). The women farmers focused their attention on post-harvest processing equipment, in contrast to the male farmers’ desire for seeding machines and on-farm tools. Milling machines and threshers were desired by the women (Table 1.1) to increase their production of flours, peanut paste and peanut oil. The differences in farming equipment desired by the focus groups emphasizes the delegation of gender roles in farming activities with women farmers being more involved in post-harvest processing (Brethenoux et al., 2011; World Food Program, 2018).

**Table 1.1** Needs of farmers and the entire community (n=59 questionnaires, n=8 FGD)

Category of needs	Expression from men focus groups	Study site	Number of references	Expression from women focus groups	Study site	Number of references
Farming needs	<b>Quality seeds:</b> <i>“The government gives very little seeds, not enough for even one person’s farm. That is why we farm a little of everything because there is not enough peanut seeds”</i>	Keur serigne djibel	FGD (2) Survey (27)	<b>Farm input:</b> <i>“It is difficult to get seeds, animal, equipment, and money. Using rented animal is expensive. It cost 6000 CFA per day to rent a machine, and 1,000 CFA per day to hire a person to plant”</i>	Ndangane	FGD (4) Survey (15)
	<b>Land availability:</b> <i>“The land available for farming is too short. There is population growth and you can’t extend the land”</i>	Keur serigne djibel	FGD (1) Survey (3)	<b>Insect attack:</b> <i>“At the producing end, even if we plow and seed well, and the crops grow well, by the time of harvest, when insects come, they can bring disease to the crop and damage the yield”</i>	Ngouye siwakh	FGD (2)
	<b>Soil fertility:</b> <i>“The soil fertility is very low, but no money to buy fertilizer”</i>	Keur serigne djibel	FGD (2)	<b>Farm income:</b> <i>“Lack of access to seeds, material, fertilizer and land. If farming, we need to borrow money for fertilizer. If the yield is however too low you will not make profit and that is like we worked for nothing”</i>	Keur serigne djibel	FGD (2) Survey (10)

**Table 1.1** continued

Commun ity needs	<p><b>Machinery:</b> <i>“More seeding machine. We have been using a seeding machine, which was given by the first Senegalese President. We need a newer seeding machine”</i></p>	Diamal (men)	FGD (1) Survey (18)	<p><b>Post-harvest processing:</b> <i>“Our milling machine is too small. If we want faster and bigger production, we need to go to other villages to make corn flour. We also want to produce vegetables but our water is not enough”</i></p>	Ngouye Siwakh (women)	FGD (11) Survey (18)
	<p><b>Food security:</b> <i>“There is not enough harvest for all the needs of the family. In the past, the harvest could feed the family for the whole year, but now it can only feed us for two months”</i></p>	Keur serigne djibel	FGD (2) Survey (9)	<p><b>Post-harvest processing:</b> <i>“Hope to have the capacity to make products and be productive. We do not have equipment to make couscous. Have training to make the product as well. Want a milling machine, as we do not have one”</i></p>	Ndangane	FGD (2) Survey (18)

### **Interest in value-added processing**

Generally both men and women smallholder farmers were interested in value-added processing and were willing to be involved in developing a value-added peanut product. More men farmers expressed interest in value-added processing in the surveys (Table 1.2) than the women, which was in contrast to the focus group discussions. Responses like *“This type of work is more for women. My wife is going to make it. Some duties are more for women,”* reemphasized the gender roles attached to peanut farming and value-added processing. Women farmers on the other hand were more willing to participate in the project with remarks like *“Yes. We have received training to make our current products (referring to the peanut paste, peanut flour, and roasted peanuts displayed at the front of the group), and so we can also receive training to make this cake product”*. All communities therefore agreed in the focus groups that any project to develop a peanut product would be carried out by the women. *“We are 40 women. We can organize and divide into groups to make the product.”*

The Keur serigne djibel and Ngouye siwakh communities also had more participants being interested in value added processing (Table 1.2) and willing to be involved in research to develop a value-added peanut product. The interest in value added processing by the Keur serigne djibel and Ngouye siwakh communities reported during the survey was also seen during the focus group discussions with women farmers. Women farmers in both communities displayed peanut products such as peanut oil, peanut paste and roasted peanuts and other products like corn and cowpea flour in the focus group discussions. The men in these two communities also affirmed their interest in value-added processing and

offered to provide support to the women in making the product. *“This type of work is more for women. Our support will be if they need money to buy equipment, we will give them the money. If they need more effort in making the product, we will help them.”*

Fewer smallholder farmers from the Diamal and Ndangane communities expressed interest in value-added processing in the surveys compared to the previous two communities (Table 1.2). Nevertheless, both male and female groups in the focus group discussions were willing to be involved in value –added processing especially in Ndagane. *“I have got an idea. We work for 2-4 months. If we make the product after harvest, we stay in the village for 6 months. This will help us avoid migration,”* responded Ndagane men to the idea of making a peanut product. Diamal women expressed eagerness to participate in the project with remarks like *“We thank you for coming here. We want you to bring income to the village with projects. We are open to partnerships”*. The disinterest in value-added processing expressed by the Diamal and Ndangane women farmers in the survey may therefore be due to the lack of ownership of wood fire ovens and other processing equipment. The existence of a market for peanut products available to Keur serigne djibel and Ngouye Siwakh explains their interest and eagerness to participate in value-added processing.

**Table 1.2** Count of participants in each community interested in value-added processing.

Participants	Communities				Total
	Diamal	Keur serigne djibel	Ndangane	Ngouye siwakh	
Male yes	3	6	3	5	17
Male no	3	0*	3	0*	6
Female yes	2	3	2	5	12
Female no	4	3	4	0*	11
Total yes	5	9	5	10	29
Total no	7	3	7	0*	17

For the same column \* indicates a significantly lower proportion at alpha level = 0.05

### **Making a value-added product**

Value-added peanut products such as Quaker Peanut Butter Baked Squares (Quaker PBBS), PB2 powdered peanut butter, Skippy P.B. Bites, and Noflaye (Senegalese peanut flour) were presented to the focus groups to stimulate ideas for a value-added product. Participants were asked to taste the products and provide feedback on the sample they preferred and will like to make. *“It’s better to do cake instead since we already have a flour product. The cake is better than Kungutu. The kids like it”* commented the groups in all four communities. Kungutu is a local Senegalese cake made by steaming the mixture of peanut paste, sugar, and millet. The participants used local peanut products made by the women to describe and compare the taste and appearance of Quakers PBBS (Table 1.3). The community members and the research team therefore defined the product development criteria as developing a peanut cake or bar similar to Kungutu (Table 1.3) and Quaker Peanut Butter Baked Squares for children. Crumbliness and a short shelf life were also identified as deficiencies in local peanut products such as Kungutu (Georges et al., 2016).

*“Why we can’t market Kungutu is because we can’t make it durable. If we can store it longer, and package it, we can sell”* said the farmers. Optimizing the texture, nutrient profile and water activity became research objectives for developing the peanut cake.

To develop a peanut product similar to both Kungutu and Quaker PBBS, the farmers suggested healthy ingredients used by mothers for feeding malnourished children (Table 1.3). Some groups also suggested ingredients used by health centers for making weaning foods for children as well as ingredients their parents used for making healthy foods in their childhood (Table 1.3). The farmers therefore shortlisted cowpea, corn, baobab powder and millet as healthy ingredients for making the peanut cake and agreed that children will be interested in a soft cohesive peanut cake.

Developing a peanut cake with the women farmers required the use of processing equipment readily available to the communities. Using available resources for developing community interventions is a key part of participatory action research and allows the target community to feel a sense of ownership in the research project (Mapfumo et al., 2013; Méndez et al., 2017). The mention of a wood oven by women in Diamal, Keur serigne djibel and Ngouye siwakh (Table 1.3) therefore gave more reason to develop a baked peanut cake. Ndangane women farmers admitted to having no wood oven in the community but were willing to use the oven in Diamal, which is a few meters away. The women farmers also stated, *“We have measuring bowls that we know the weight of”*, which resolved the issue of weighing out ingredients. The presence of multi-purpose grinders

(Table 1.2) supplied by Bountifield International (Appropriate Technology, 2013) validated the use of flours from healthy ingredients like cowpea and corn (Table 1.3) for making the peanut cake.

**Table 1.3** Ideas on making a value-added peanut product expressed by smallholder farmers

Process	Expression from men focus groups	Study site	Number of references	Expression from women focus groups	Study site	Number of references
Identifying existing peanut products	<b>Local value added products:</b> <i>“Sousale is similar to the peanut cake. It is a big cake cut in small pieces like kungutu. It is made by mixing the grilled peanut flour with millet flour and steaming it”</i>	Keur serigne djibel	FGD (2)	<b>Local value added products:</b> Peanut snack (peanut + salt or sugar), like a cake. <i>“It is hard. It is a grilled product. Sugar with groundnut, heat sugar and it melts then put groundnut on it and makes it a hard cake”</i>	Diamal	FGD (1)
	<b>Reference peanut products:</b> <i>“This has a kungutu-like taste”</i> Referring to Quaker peanut butter baked squares	Ngouye siwakh	FGD (1)	<b>Reference peanut products:</b> <i>“Yes we like the Quaker peanut butter baked squares and it taste like kungutu”</i>	Ngouye siwakh	FGD (4)
Identifying healthy Ingredients	<b>Weaning foods:</b> Millet, corn, rice, cowpea, peanut paste. <i>“Keungheul makes a flour from these ingredients. It is good for malnourished children.”</i>	Keur serigne djibel	FGD (2)	<b>Weaning foods:</b> <i>“I have a good recipe: Lahou bissap, cracked millet, groundnut flour or paste, dried fish, hibiscus, peanut paste. This is good for the kids who are unhealthy”</i>	Ndanga ne	FGD (5)
	<b>Healthy ingredients:</b> <i>“Baobab can be good for malnourished children. The product we make which is close to the Senegal noflaye that you showed us, we add baobab powder to it.”</i>	Keur serigne djibel	FGD (4)	<b>Pre-colonial foods:</b> <i>“Our childhood, we were eating more of Pearl Millet Couscous with milk or yogurt. When you were hungry or malnourished, that is what our mother’s gave us.”</i>	Ngouye Siwakh	FGD (9)

**Table 1.3** continued

Identifying processing equipment	<b>Availability of equipment:</b> <i>“Yes, they will be willing to share their oven with us, because they have been doing it with others also”</i>	Keur serigne djibel	FGD (1)	<b>Choice of processing method:</b> <i>“The traditional oven is preferable. The women do not own it. My son-in-law owns it.”</i>	Diamal	FGD (2)	
	<b>Availability of equipment:</b> <i>“We have a gas oven”</i>	Diamal	FGD (1)	<b>Post-harvest equipment:</b> <i>“Yes, we have a grinder in our village”</i>	Ngouye siwakh	FGD (4)	23
	<b>Availability of equipment:</b> <i>“We can support them to build an oven.”</i>	Ngouye siwakh	FGD (2)	<b>Ownership of equipment:</b> <i>“Baba Ka Ndao can let us use the oven. That is my brother and so I can use the oven free”</i>	Ngouye siwakh	FGD (5)	

### **Evaluation of focus group discussion and project outcome**

A post focus group survey was conducted in order to ensure satisfaction of participants with the research approach, to collect feedback from the participants for the next steps, and to further deepen the sense of ownership of the project (Méndez et al., 2017). All participants were satisfied with the approach, were willing to participate in the project and were excited at the prospects of making commercial value-added products (Table 1.3). Participants recommended the project start before the harvest in order to be ready for processing immediately after harvest (Table 1.3). *“It is not difficult to access ingredients but corn and peanuts are expensive in the lean period (when not in harvest), 600CFA per kg now, 300CFA during harvest”* emphasized Diamal women farmers.

The results of the focus group discussions were used to develop a peanut cake prototype with some healthy ingredients suggested by the participants (Allan et al., 2020). Three basic recipes were developed with peanut paste and varying levels of cowpea flour, corn flour and baobab powder as the main ingredients. The samples were then provided to the women farmers in each of the four communities to taste and provide feedback (Table 1.3). The women leaders were satisfied with the taste and compared it to the Quaker PBBS introduced to them during the focus group discussions (Table 1.3). The texture of the prototypes were however identified as brittle, which served as a point for making improvements to the product. The sample tasting results were used to develop a formal product development technical research (Allan, Kinnare, et al., 2020) for optimizing the texture, taste, shelf life and nutrition.

Comments from the post focus group survey were used to improve the texture of the peanut cakes by adding acacia gum, which has been reported to improve the texture of gluten-free baked products (Michail, 2017). Women's groups were therefore comfortable with the process of making the peanut cakes on the second trip and proceeded to create their own shapes after the demonstration. The women farmers named the product "Bonbonbuoye" which literally translates as baobab candy. The women appreciated the taste and texture of the peanut cake, however they advised a reduction in baobab and salt. "*The sugar is fine but lower down salt, the baobab is too high and salt is too high*" they said. Proposed prices of the peanut cake ranged between 100-150CFA with the women suggesting a brown paper bag for the package. The women however had to rent an oven for the demonstration in Diamal and in Keur serigne djibel reported a damaged oven, which could not be used at the time.

**Table 1.4** Comments on focus group discussion and peanut cake prototypes by participants

Stakeholders	Comments	Study site
Participants opinions on the focus group discussion	<ul style="list-style-type: none"> <li>• Comments on the focus group discussion: <i>“The focus group allowed us to see that we can have other products from our local products”</i></li> </ul>	Ngouye siwakh
	<ul style="list-style-type: none"> <li>• Timeline: <i>“We want the project to start activities before the harvest”</i></li> </ul>	Diamal
	<ul style="list-style-type: none"> <li>• Expectation: <i>“Following the focus group with the information shared, we are impatient to see the execution of the project and the results it will have in the village”</i></li> </ul>	Ndangane
	<ul style="list-style-type: none"> <li>• Comment on the focus group discussion: <i>“We are happy with the approach adopted and the focus group process and invite you to act quickly in the implementation of the project”</i></li> </ul>	Keur serigne djibel
Women’s Leaders comments on peanut cake prototypes	<ul style="list-style-type: none"> <li>• Taste: <i>“We love the tastes of the peanut cake prototype and think it has vitamins”</i></li> </ul>	Ndangane
	<ul style="list-style-type: none"> <li>• Stability: <i>“The square peanut cake is easier to keep and therefore more suitable for the village”</i></li> </ul>	Diamal
	<ul style="list-style-type: none"> <li>• Taste: <i>“The taste of the peanut cake prototype is better; the peanut smells better and more consistent”</i></li> </ul>	Ngouye siwakh
	<ul style="list-style-type: none"> <li>• Texture: <i>“The peanut cake prototype is too brittle”</i></li> </ul>	Keur serigne djibel

## **Discussion**

This study seeks to increase the potential of value-added processing with farmers in Kaffrine, Senegal to create more opportunities to improve farmers' income and to develop nutritious products for school-age children. The use of participatory action research however allows the farmers to have a stake in the product development process and define the research objectives. Other studies in product development for communities either leave out farmers (Dlamini & Sciences, 2016) or have them play a minor role in the research process and collaborate more with local scientists and research labs (De Groote et al., 2018)

The use of surveys prior to contact with the communities therefore informed the research design and the choice of focus group discussions as the main tool for data collection and community collaboration. The surveys showed the willingness of the communities to be involved with the study which has been observed in studies to instigate community development in sub-Saharan Africa (Mapfumo et al., 2013; Wanjuu et al., 2018). The survey also showed the awareness of the farmers of community issues of malnutrition and poverty and the lack of opportunities to make profit from peanut farming (Table 1.1). Men farmers were however more willing to participate in the study from the survey results which can be associated to the ownership of land and other farm resources by predominantly men in sub-Saharan Africa (Jones & Christie, 2014).

Focus group discussions with the smallholders revealed more issues with peanut farming, value-added processing of peanuts and community development. Communities with more involvement in peanut processing like Ngouye siwakh and Keur serigne djibel had more issues with farming and were more interested in product development and marketing. This

validates the positive impact of value-added and post-harvest processing on farming (Brethenoux et al., 2011; World Food Program, 2018). Community needs were also discussed in the focus groups and highlighted the “wicked” problems of health and malnutrition (Dunkel, 2018; Sowell et al., 1999) which can be tackled by empowering women in farming (World Food Program, 2018). The presence of Bountifield International (Appropriate Technology, 2013) in the focus group discussions also stimulated information on the equipment needs of the communities. Statements such as “*Our milling machine is too small. If we want faster and bigger production, we need to go to other villages to make corn flour*” served as feedback on post-harvest machinery purchased by the communities.

Focus group discussions have been used as a means of informing product development (Mied & Bruseberg, 2000) but utilize the opinions and preferences of consumers in product design. This study focused on smallholder farmers as both producers and consumers and based product design on their suggestions and preferences. Farmers especially women were knowledgeable about food ingredients to use for product development and offered substitutes to wheat flour used in Quaker PBBS. The women farmers also specified amounts of ingredients to be used especially baobab powder which is a novel ingredient and is underutilized in food product development (Kitano & Zenko, 2017). “*Yes, you can add baobab but it has to be in small quantity. Baobab has a strong taste,*” the women farmers advised. Baobab powder obtained from the pulp of the baobab fruit grows wildly in Senegal (Kamatou et al., 2011) and the inclusion of baobab as an ingredient contributes to efforts to preserve wild fruit trees in sub-Saharan Africa (Simel & Johns, 2009)

All four communities suggested the use of a wood fire oven as the most feasible processing method due to the textural and shelf stability observed in baked products (Khattoon et al., 2009) like Quaker Peanut Butter Baked Squares. The proximity of Ndangane to Diamal known to have an oven also made the choice of baking feasible despite the absence of an oven in Ndangane. Equipment like grinders for milling corn, cowpea and peanuts provided by Bountifield International to all four communities also improved accessibility to flour and peanut paste allowing all ingredients to be sourced directly from the community.

The use of a survey to evaluate the satisfaction and involvement of the communities in the project serves as a means of triangulation (Cohen & Crabtree, 2006) and follows the PAR approach of continuous involvement of partners (Bayala & Dayamba, 2016; Méndez et al., 2017). The communities reported to be pleased with the research teams' approach of discussing issues in the community and searching for solutions within. The assessment of the prototypes of peanut cake sought to involve the women farmers in the entire process as dictated by the PAR approach (Bayala & Dayamba, 2016). The brittle texture pointed out by the women's leaders also informed the use of acacia gum in improving the textural stability (Michail, 2017) of the peanut cakes developed (Allan, Kinnare, et al., 2020).

Feedback from the women's leaders were used to improve the peanut cakes, which were accepted and easily made by the women during the demonstration. The successful development of the peanut cakes with the smallholder women farmer reinforces the use of participatory action research in community development. The geographical distance between the research team and the target community however put a strain on continuous communication as well as resources available for the project. The creation of a value-added

peanut product with the smallholder women farmers will potentially improve farmers' income however, the farmers still struggle with aflatoxins and ownership of equipment necessary to carry out value-added processing.

## **Conclusion**

This study aims to collaborate with smallholder peanut farmers in Kaffrine Senegal via participatory action research to gather their needs, interests, recommendations and feedback on developing a culturally acceptable, nutritious, value-added peanut product. The participatory action research approach allowed the involvement of the smallholder farmers in the research process and developed a partnership between the four communities and the research team. Conducting surveys before the focus group discussions helped to inform the research team of the prevailing situation in the communities and served as a reference for focus group transcripts. The focus group discussion identified the women farmers as responsible for post-harvest processing in the communities and therefore more likely to adapt the product after development. Cowpea flour, corn flour and baobab powder were identified as potential ingredients in and were processed using grinders available in all four communities. Using equipment available in the communities such as wood fire ovens and multipurpose grinders ensures the sustained production of the peanut cake. Continuous communication with the communities through surveys and interactions allowed the peanut cake to be developed according to the preferences and specifications provided during the focus group discussion. The knowledge of ingredients and processing displayed by the smallholder women farmers therefore questions the exclusion of farmers in community interventions to food security and postharvest losses.

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CHAPTER TWO

DEVELOPING CULTURALLY ACCEPTABLE PEANUT NUTRITION BARS WITH  
SMALLHOLDER WOMEN FARMERS IN KAFFRINE, SENEGAL USING  
RESPONSE SURFACE METHODOLOGY

Contribution of Authors and Co-Authors

Manuscript in Chapter 2

Author: Edwin Allan

Contribution: Edwin Allan developed the peanut nutrition bars, performed the analysis, interpreted results and wrote the manuscript.

Co-Author: Dr. Wan-Yuan Kuo

Contribution: Dr. Wan-Yuan Kuo provided expertise in product development and analysis and edited the manuscript, figures and tables.

Co-Author: Emily Raber

Contribution: Emily Raber determined the nutrition profile and texture properties of peanut nutrition bars

Co-Author: Aliou Ndiaye

Contribution: Conducted sensory consumer acceptance tests with school age-children

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**Abstract**

Smallholder women farmers in Senegal, engaging in value-added agriculture, have the potential to improve farm income and food insecurity. A peanut nutrition bar was therefore developed with supports of smallholder farmers in Kaffrine, Senegal, informed with the use of healthy Indigenous ingredients and community-feasible methods gathered in the previous focus group interviews. This study used response surface methodology (RSM) with a central composite design to optimize the formulation for making the peanut nutrition bars. The RSM design included two formulation factors, the weight ratio of cowpea flour to corn flour, and the weight percentage of baobab powder in the cowpea-corn-baobab blend. The influence of the two formulation factors on the texture properties, nutrition profiles, water activity, and consumer acceptance was investigated. Cohesiveness and gumminess of the peanut nutrition bars were dependent on both the ratio of cowpea flour to corn flour and percent baobab powder in the mixture. Protein and folate contents were found to be dependent on the ratio of cowpea flour to corn flour and a decrease in water activity was observed with increasing percent baobab powder in the mixture. Statistical differences were not observed between the acceptance scores of peanut nutrition bars with baobab powder levels between 10-20% (w/w, d.b.), a Senegal local peanut product and an industry optimized peanut product. Formulations with cowpea flour to corn flour ratios between 50-75 and baobab levels below 20% were identified as having suitable texture, nutrition content and water activity to be easily adapted by the smallholder women farmers in Kaffrine.

**Introduction**

It was reported that 63 different products from raw peanuts could be developed and could potentially gain higher revenue for farmers and improve food security (Dong & Sylla, 2010). Edible and shelf-stable peanut products are however not widely available in the domestic market in Senegal, the 9<sup>th</sup> largest producer of peanuts globally (Georges et al., 2016). This gap in the peanut value chain created the opportunity to work with smallholder peanut farmers in Senegal to develop a value-added and nutritious bar for the local market.

Peanut production provides income for more than 70% of rural households in Senegal (Tankari, 2012) and employs a large number of the rural population (Ndiaye et al., 2018). The value addition of peanuts represents about 3% of total value added in Senegal's agriculture (Tankari, 2012). However, smallholder peanut farmers on large do not profit proportionately from the sale of harvested peanuts or the transformation into semi-finished and finished products. It was noted that smallholder peanut farmers earn only \$8 for a ton of peanuts produced, whilst middlemen earn \$14 and the industries \$90 (Dong & Sylla, 2010). Interventions by the government to improve farming outcomes and develop value-added products from crops continue to prove unfeasible owing to the absence of smallholder farmers in decision making (Cisse, 2014; Tankari, 2012).

In addition to the low-income situations, the limited number of edible and shelf-stable peanut products in the domestic market despite the demand contributes to food insecurity in Senegal (Georges et al., 2016). Undernutrition in Senegal is attributed to 31 percent of all child deaths and micronutrient deficiencies remain alarmingly high (USAID, 2015). The shortage of edible and shelf-stable peanut products on the Senegalese market has been

associated with run-down machinery, aflatoxin contamination and a lack of incentives for farmers (Georges et al., 2016). Common peanut products in Senegal include peanut oil, peanut paste, roasted peanuts and peanut cakes (e.g. Kungutu) (Georges et al., 2016), which are mostly used in food preparation or eaten in conjunction with other foods. The use of peanuts in daily meal preparation in Senegalese households highlights the demand for more peanut products (Georges et al., 2016) which satisfy local preferences and provide the opportunity for value-added peanut production by smallholder farmers (Gapasin et al., 2005).

Peanuts are cultivated throughout Senegal but predominantly in Kaolack, Kaffrine, Diourbel and Louga which form the peanut basin of Senegal (Elizabeth et al., 2015; Georges et al., 2016). A survey and focus group interviews were conducted in four communities with men and women smallholder peanut farmers in the Kaffrine region (Allan, Kim, et al., 2020), which lies in the center of Senegal's peanut basin (Elizabeth et al., 2015). The results of the discussion indicated a strong interest in developing a peanut nutrition bar similar to Quaker® Peanut Butter Baked Squares (Quaker PBBS) but using local crops and ingredients from wildy grown Indigenous plants. The men and women farmers were both interested in a peanut nutrition bar, the men, however, mentioned the women as being responsible for food processing (Allan, Kim, et al., 2020) which reflected the critical role of women in West Africa's value-added agriculture (World Food Program, 2018).

The project leading to the present study relied on a participatory action research model (Bayala & Dayamba, 2016; Méndez et al., 2017) which employs surveys, focus group

discussions and general interactions with farmers to inform the choice of ingredients and desired qualities for a nutritious peanut bar (Allan, Kim, et al., 2020). Participatory action research allows the development of feasible social change methods with the target community, which in this case allowed the smallholder farmers to determine the direction of the research (Méndez et al., 2017). Previous attempts to develop value-added products in Senegal were conducted to collaborate with food processing and innovation laboratories, without much input from smallholder farmers on product design and development (De Groote et al., 2018; Mohammed, 2007). Edible products developed from such projects have therefore not been adapted by the rural communities and have not improved the household income of farmers (De Groote et al., 2018; Mohammed, 2007).

Studies on developing value-added products from peanuts and other local Senegalese ingredients have shown promising results in the domestic market (De Groote et al., 2018). Consumer acceptance tests and surveys conducted for value-added products in Senegal show a high preference and a willingness to pay for better quality products (De Groote et al., 2018). To optimize product quality, response surface methodology (RSM) has been used in food product development for exploring product formulations (Santos et al., 2018). The RSM approach uses linear and or quadratic models to determine the optimum conditions or levels of an independent variable (Lenth, 2012). Developing a culturally acceptable peanut nutrition bar approached from participatory action research assisted with the RSM experimental design offers an opportunity for Senegalese smallholder farmers to improve the community nutrition security while profiting from the value-added product.

The objective of this study was therefore to (1) use response surface methodology to formulate and develop a peanut nutrition bar with local Senegalese ingredients informed from the previous participatory action research; and (2) determine the texture properties, nutrition profiles, water activity, and consumer sensory acceptance of the peanut nutrition bars made with varying levels of cowpea flour, corn flour, and baobab powder. The incorporation of Senegalese food culture and Indigenous ingredients in food product design helps to strengthen the local food identity, encourages consumer support for local crop diversity, and minimizes the adoption of western universal foods (Noack & Pouw, 2015; UNESCO, 2019). The outcome of this study can provide a foundation for value-added processing led by smallholder women farmers, and provides insights to culturally acceptable product development for improving the economic, nutrition, cultural, and environmental sustainability of Senegal's food system.

## **Materials and Methods**

### **Materials**

Peanut paste, cowpea flour, corn flour, and baobab powder were directly sourced from the partnering smallholder women farmers in Keur serigne djibel, Kaffrine, Senegal. Acacia gum was purchased from Anthony's Organic Acacia Senegal Powder (Los Angeles, California). Sugar, canola oil, baking powder and salt were obtained from local grocery stores.

Quaker® Peanut Butter Baked Squares (Quaker PBBS, Quaker, Salem, New Jersey) was purchased to represent an industry-optimized peanut product and Kungutu, a local Senegalese peanut product was purchased from the partnering smallholder farmers in Keur serigne djibel to represent the local peanut product.

The moisture content of the corn flour, cowpea flour and baobab powder were determined in triplicates with a moisture analyzer (Mettler-Toledo HC103, Columbus, Ohio). Cowpea flour had a moisture content (w/w, w.b.) of 8.48%; corn flour 8.95% (w/w, w.b.) and baobab powder 6.47% (w/w, w.b.).

### **Methods**

#### **Response surface methodology (RSM) design for peanut nutrition bar formulation**

Preliminary trials were conducted to choose the appropriate ingredient combinations as well as suitable ranges of different ingredients for making the peanut nutrition bar. The RSM design was conducted with SAS 9.4 (SAS, Cary, North Carolina) to evaluate the

effects of two formulation factors on the texture properties, nutrition profiles, water activity, and consumer acceptance of the peanut nutrition bars. Factor I represents the weight ratio of cowpea flour to corn flour and factor II represents the weight percentage of baobab powder in the cowpea-corn-baobab blend of the formulation (Table 2.1). The corresponding values for the two factors with three levels of variation ( $2^3$ ,  $\alpha = 1.414$ ) and their combinations for each formulation were determined using a central composite design and were displayed in Table 2.1. The response variables were analyzed and modeled using the equation:

$$Y = \beta_0 + \sum \beta_i X_i + \sum \beta_{ii} X_i^2 + \sum \beta_{ij} X_i X_j + \varepsilon$$

Where  $Y$  is the predicted response;  $\beta_0$  is a constant;  $\beta_i$  is the linear coefficient;  $\beta_{ii}$  is the squared coefficient;  $\beta_{ij}$  is the cross-product coefficient; and  $\varepsilon$  is the random error associated with the response. 3-dimensional response surfaces and contour plots for each response variable were made using SAS 9.4 according to the predicted model equation.

### **Peanut nutrition bar preparation**

The peanut nutrition bar formulation consisted of the following ingredients on a wet basis, 11-41.6 g flour (cowpea-corn flour blend), 29.3 - 29.4 g water, 23.0 g white sugar, 5.2 - 15.6 g baobab powder, 13.0 g peanut paste, 10.8 g canola oil, 2.0 g baking powder, 0.0 or 1.56 g acacia gum, and 1.2 g salt, and. As shown in Table 2.1, twelve experiments were designed with different combinations of the two factors. Water added to the formulations was varied in order to achieve same moisture content between each formulation prior to baking.

The cowpea-corn flour blend, baobab powder, white sugar, baking soda, and salt were mixed to form the dry mixture. Acacia gum and canola oil were first mixed with water, and then mixed with the peanut paste to form the wet mixture. The final dough was achieved by blending the wet mixture and dry mixture with a spatula until a homogenous color was obtained. The dough was settled at room temperature for 30 min covered with plastic wrap. A rectangular pastry cutter of 25.9 mm \* 30 mm \* 70mm dimension was applied to shape the dough (126 g/ formulation), to make one peanut nutrition bar per formulation. The peanut nutrition bars were then baked in an electric convection oven (Blodgett Convection Oven, Essex Junction, Vermont) at 177°C for 12 minutes, with the tray turned 180° at the 6<sup>th</sup> minute. The baked peanut nutrition bars were cooled off on a rack. The peanut nutrition bars were named based on the ratio of cowpea flour to corn flour (w/w., d.b.) and the percentage of baobab powder in the cowpea-corn-baobab blend (w/w., d.b.) as shown in Table 2.1. For example, 50:50, 20% denotes the peanut nutrition bar made from equal weight amounts of cowpea and corn flour with 20% baobab powder in the cowpea-corn-baobab blend.

### **Texture properties**

Texture profile analysis was performed on the peanut nutrition bars, Quaker PBBS, and Kungutu using TA.XT Plus texture analyzer and software (Texture Technologies, La Crescenta, CA). The texture analyzer was equipped with a TA-40 4-inch diameter cylindrical probe and a 50 kg load cell. The peanut nutrition bars were cut into 2<sup>3</sup> cm<sup>3</sup> cubes, and each cube was compressed at 1.0 mm/sec until reaching 50% strain, after which the probe returned to starting position and repeated another compression using the same speed and strain. Three batches were prepared for each of the 12 peanut nutrition bar

formulations, and five measurements were performed for each batch. Hardness, cohesiveness and gumminess of the samples were calculated based on the force of compression and the height of compressed samples.

### **Nutrition evaluation**

The nutrition composition of the 12 formulations were determined with Food Processor software (ESHA Research, Salem, Oregon). Protein, fiber, folate, vitamin C, vitamin A, calcium and iron were evaluated separately in each formulation.

### **Water Activity**

The water activity of all twelve peanut nutrition bars, the Quaker PBBS, and Kungutu were determined using the Aqualab water activity meter (MeterFood, Pullman, Washington). The meter was calibrated with deionized water and a standard saturated salt solution before use. Three batch preparations were made for each of the 12 formulations, and three measurements were made for each batch preparation.

### **Consumer Acceptance Test**

Two separate consumer acceptance tests were conducted in Senegal. The first test used adult consumers for evaluating all 12 peanut nutrition bars. The second test used school-age children to evaluate three selected peanut nutrition bars. Approvals from the Institutional Review Board at Montana State University were received prior to both studies (Approval number EA032819-EX).

In the first consumer test, A total of 149 participants age 18 or above who self-declared to have no dietary restrictions were recruited at the 2020 Kaolack International Trade Fair (FIKA) in Kaolack, Senegal. A 9-point hedonic scale test was performed to assess the consumer acceptance of the peanut nutrition bars and two other reference products, the Quaker PPBS and Kungutu. The 12 different formulations were randomly split and placed in three tables with 4 formulations in each table. Each table also presented the Quaker PBBS and Kungutu. Each participant was randomly assigned to one of the three tables to evaluate the 6 samples including Quaker PBBS, Kungutu, and the 4 peanut nutrition bars. Participants were instructed to taste the sample and rate for the overall liking from “Dislike extremely” (1 point), “Neither like or dislike” (5 point) to “Like extremely” (9 points). Participants were instructed to rinse their palate with room temperature water between samples. All samples were labelled with random 3-digit codes. The testing ballot was written in French, and instructions were orally explained to participants in French or in Wolof (Senegalese local language).

In the second consumer test, 121 school-age children (8 – 12 years old) with no dietary restrictions were recruited from A.K.F-Wakhinane School in Guediawaye, Senegal, with signed permissions from their guardians or teachers. Three selected peanut nutrition bars, 0:100, 20%, 50:50, 20%, and 100:0, 20%, (samples 8, 6, and 7 in Table 2.1, respectively), were evaluated by each participant. A graphic 9-point hedonic scale test with upset to smiley faces was used to assess the children’s acceptance of the peanut nutrition bars. The children were asked to taste the product and select a graph that could describe the overall liking from “Dislike extremely” (upset face, 1 point) to “Like extremely” (smiley face, 9

points). Participants were instructed to rinse their palate with room temperature water between samples. The ballot was written in French and the instructions were explained to the children in French.

### **Statistical analysis**

The data in this study were processed using Rstudio Version 1.2.1335 (Rstudio Inc, Boston, Massachusetts). Variance analysis (F test), R<sup>2</sup> values, lack-of-fit test and diagnostic plots such as normal and residual plots were conducted to check the RSM model adequacies. One-way analysis of variance (ANOVA) and Fisher's least significant difference test were used to compare the means between samples for texture properties, water activity and consumer acceptance scores. Student's t-test was performed to compare the texture properties of the peanut nutrition bar with and without the addition of acacia gum and to compare the consumer acceptance of the peanut nutrition bar by different groups of gender and ages.

## **Results and Discussion**

### **Effect of acacia gum on the texture properties of peanut nutrition bars**

The focus group discussion with the smallholder women farmers in the previous study indicated softness being important texture attributes for products meant for children. The partnering women farmers also identified the cohesive texture in Quaker PBBS to be desirable and could be the texture index for the value-added peanut product (Allan, Kim, et al., 2020). In addition, the previous focus group study reported that crumbliness was one of the primary factors for the low marketing potential of the local peanut cake, Kungutu, despite the high consumer acceptance for its taste (Table 2.5). Crumbling occurs in cakes as binding water evaporates to the external environment by moving from the crumb to the crust, therefore results in a reduction in hardness, gumminess, and cohesiveness (Milner et al., 2020).

Acacia gum has been used in baking operations to improve the texture of bread especially in gluten-free baking or using flours with undesirable texture properties (Michail, 2017). The addition of acacia gum significantly decreased the hardness and either maintained or increased the cohesiveness for most of the peanut nutrition bars, which is a desirable effect (Table 2.2, Figures 2.1 and 2.2). Therefore, the peanut nutrition bars with acacia gum were used in measuring nutrition profile, water activity, and consumer acceptance. Without acacia gum, the hardness and gumminess of the peanut nutrition bars were dependent on the level of baobab powder and not the ratio of cowpea flour to corn flour (Figure 2.2 and Table 2.3). The absence of acacia gum also made the cohesiveness of the peanut nutrition bars independent of either of the two formulation factors. The addition of acacia gum led

to the dependence of cohesiveness on both formulation factors (Table 2.3). This suggested the potential interactions between acacia gum and the polymers in cowpea flour, corn flour, and baobab powder, which altered the microstructure and texture of the peanut nutrition bars.

### **The texture properties of peanut nutrition bars with acacia gum and varying levels of cowpea flour, corn flour, and baobab powder**

The following discussion pertains to the peanut nutrition bars with acacia gum. Based on Table 2.2 for the peanut nutrition bars with acacia gum, most of the bars (samples 1, 2, 3, 6, 7, 8, 10, 11) bear hardness comparable to Kungutu. Furthermore, all of the bars showed cohesiveness higher than Kungutu, and most of the bars (samples 1, 2, 3, 5, 6, 7, 9, 10, 11, and 12) bear cohesiveness comparable or higher than Quaker PBBS. Samples 2, 3, 4, 5, 9, 11, and 12 presented gumminess higher than Kungutu. The above comparisons suggested that some of the peanut nutrition bars presented soft, cohesive, and gummy texture that would be desirable for the Senegal local market.

Baobab powder has been reported to have high levels of pectin, which functions as a thickener in foods due to its high gelling ability (Kitano & Zenko, 2017; Muthai et al., 2017), thus baobab powder was frequently applied in thickening food products such as jams and juices (Kitano & Zenko, 2017). Nowadays, increasing applications of baobab powder in baking have been documented as well (Kamatou et al., 2011; Kitano & Zenko, 2017). At a fixed ratio of cowpea flour to corn flour (50:50), the hardness of the peanut nutrition bars with acacia gum increased from 1102.2 to 2431.9 when the percent baobab

powder in the cowpea-corn-baobab blend increased from 10% to 30% (samples 10 and 9 in Table 2.2). This increase in hardness of the peanut nutrition bars with an increased level of baobab powder can also be observed from the RSM surface and the regression coefficient (Figure 2.1 and Table 2.3, respectively). For the peanut nutrition bars with acacia gum, with the ratio of cowpea flour to corn flour equal to or over 50:50 and with the percent baobab powder in the cowpea-corn-baobab blend over 20%, the hardness was higher compared to Kungutu (samples 4 and 9 in Table 2.2).

From the RSM coefficients, the cohesiveness of the peanut nutrition bars containing acacia gum was negatively correlated with  $X_1$ ,  $X_2$ , and their interaction (Table 2.3), implying that increasing the ratio of cowpea flour to corn flour or the increasing the level of baobab powder negatively impacted the cohesiveness of the products. Sample 3, 7 and 10, which had a ratio of cowpea, flour to corn flour at 50 % and or above with low levels of baobab powder (Table 2.2) had a higher cohesiveness out of the twelve formulations. It has been reported that smaller particle size flours such as cowpea have a higher cohesion due to an increased surface area for moisture absorption (Mamat et al., 2012). The presence and increasing levels of baobab powder acts as a humectant (Kitano & Zenko, 2017), absorbing moisture in the mixture and consequently reduces the cohesiveness of the resulting peanut nutrition bars. Nevertheless, the peanut nutrition bars with acacia gum were all observed to be significantly more cohesive and gummier than Kungutu (Table 2.2). Gumminess of the peanut nutrition bar containing acacia gum was negatively correlated with the  $X_1^2$  and the interaction of  $X_1$  and  $X_2$ . The impact of the two factors (ratio of cowpea flour to corn flour and the percentage of baobab powder) were showed to correlate with cohesiveness

and gumminess of the peanut nutrition bars (Table 2.3). An increase in the ratio of cowpea to corn flour was observed to cause a decrease in gumminess (Figure 2.1).

### **The nutrition profile of peanut nutrition bars with acacia gum and varying levels of cowpea flour, corn flour and baobab powder**

Table 2.4 shows the nutrition content and percent RDI of the nutrients in the peanut nutrition bars. Overall, the peanut nutrition bars contained adequate levels of protein, fiber, folate, vitamin C, calcium and iron, which are of public health significance, vitamin A and zinc were found to be lacking due to the limited amounts of vitamin A foods in Kaffrine (Badiane et al., 2018).

The peanut nutrition bars provided 420 – 447 kcal of energy per bar of 120 g, which is at least 35% of recommended daily calorie intake for school-age children (8 - 12 years) (reference). The recommended dietary allowance of protein for school-age children ranges between 19 - 34 g, essential for optimal growth and brain development (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). The protein content of the peanut nutrition bars developed from this study fell between 8 - 13 g per bar (23.5 - 68.4% Recommended Dietary allowance, RDA, and increased with increasing ratio of cowpea flour to corn flour (Tables 2.4 and 2.5). The combination of cowpea and corn flours were reported to provide complete protein stemming from the complementary action of amino acids in legumes and grains (FAO, 1992) and had been applied in making weaning foods (Ngoma et al., 2018). Calcium (447 - 490 mg), iron (3 - 4 mg), and folate (10.4 - 263.3 µg) also increased solely with increasing ratio of cowpea flour to corn flour (Tables

2.4 and 2.5, Figure 2.3). The peanut nutrition bars with the ratio of cowpea flour to corn flour at 50:50 or more provided at least a quarter of the dietary reference intake of calcium, iron, and folate for school-age children (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015).

The fiber content in the peanut nutrition bars was positively correlated with both the ratio of cowpea flour to corn flour and the level of baobab powder (Table 2.5). This agreed with findings that cowpea and baobab contained high amounts of fiber (Muthai et al., 2017; Ngoma et al., 2018). Increasing the level of baobab powder increased the levels of fiber (8 - 12 g) and vitamin C (4.5 - 12.8 mg) in the peanut nutrition bars, and the bars with 30% baobab powder provided at least half of the RDA for school-age children (Tables 2.4 and 2.5, Figure 2.3).

### **The water activity of peanut nutrition bars with acacia gum and varying levels of cowpea flour, corn flour and baobab powder**

Water activity, unlike moisture content, is a measure of the water available to take part in chemical reaction, and can be used as an estimation of a food's shelf life (Sandulachi, 2016). A water activity level of 0.85 or less is suitable to prevent the growth of pathogenic bacteria (Bacon, 2012), and below 0.6 can prevent the growth of all microorganisms (Bacon, 2012; Sandulachi, 2016). A regression model was fitted to explain the observed changes in water activity of the peanut nutrition bars with the ratio of cowpea flour to corn flour and the level of baobab powder (Table 2.5). The water activity of the peanut nutrition bars was observed to decrease from 0.77 to 0.73 with an increase in the level of baobab

(Samples 1 and 9 in Table 2.4,  $p < 0.05$ , Figure 2.4). Previous study reported that baobab could reduce water activity and thus increase shelf life due to the high levels of pectin in baobab which acted as a humectant and bound to water (Kitano & Zenko, 2017). The water activity was not correlated with the ratio of cowpea flour to corn flour (Table 2.5). Nevertheless, the shelf stability of the peanut nutrition bars could potentially be strengthened by cowpea globulins as well which were reported to be effective antibacterial agents (Abdel-Shafi et al., 2019). Future storage studies can complement the water activity to inform the shelf stability of the peanut nutrition bars.

### **The consumer sensory acceptance of peanut nutrition bars with acacia gum and varying levels of cowpea flour, corn flour and baobab powder**

Two groups of participants including Senegalese adults and school age children evaluated the peanut nutrition bars for sensory acceptance. A product prototype with the sensory acceptance score of 6 or higher on a 9-point hedonic scale implied market potential (The National Academy of Science Engineering Medicine, 2020). Overall, most of the peanut nutrition bars (samples 1 - 3, 5, 6, 8, 10 - 12 in Table 2.6) evaluated by the adults received average acceptance above 6 out of 9. All three of the selected peanut nutrition bars evaluated by the school-age children received average acceptance above 7 out of 9 (Table 2.6).

From the adult sensory test, the overall acceptance of Kungutu (local Senegalese peanut cake) ranged between (8.0 - 8.5). Such an appreciation for this local value-added product represents a potential market opportunity for peanut nutrition bars made by the smallholder

women farmers. Average acceptance scores between 7.0 and 7.4 were observed for Quaker® PBBS but were not significantly higher than 75:25, 15% (sample 3 in Table 2.6). The Quaker® PBBS was used as a reference in the prior focus group discussions to explore desirable product criteria (Allan, Kim, et al., 2020). Having the developed peanut nutrition bar sharing comparable sensory acceptance as the Quaker PBBS suggests the effectiveness of using participatory action research in developing community-based interventions (Mapfumo et al., 2013; Méndez et al., 2017). The consumer acceptance tests conducted by Groote et al. (2017) in Touba, Senegal were unable to obtain distinctions in samples from participants, which was not helpful in identifying the true market potential of the products. The clear differences in the overall acceptance between the peanut nutrition bars shows genuine appreciation and a potential for adaptation and commercialization of the high scoring peanut nutrition bars.

The average acceptance scores of the developed peanut nutrition bars evaluated by the adults fell between 4.9 and 7.5 (Table 2.6 and Figure 2.4), and was negatively correlated with  $X_2$  and the interaction between  $X_1$  and  $X_2$  (Table 2.5). Such correlations suggested the negative impact on the sensory acceptance of the peanut nutrition bars by the baobab powder and its interaction with the cowpea flour. A greater decrease in the average acceptance scores was observed for the peanut nutrition bars with baobab levels of 25% and above compared to the bars with lower levels of baobab (Figure 2.4). The above finding was support by the previous study, in which the smallholder women farmers from the focus group discussions advised against using high amounts of baobab powder due to its sour taste (Allan, Kim, et al., 2020). Also, cowpea flour levels above 50% in composite flours

have been reported to impart a beany and metallic aftertaste in cowpea-fortified products (Dlamini & Sciences, 2016), which may explain the negative sensory impact by the interaction between  $X_1$  and  $X_2$  mentioned above.

Table 2.6 includes the average acceptance of the peanut nutrition bars by gender and age groups. The choice of age grouping, 18 - 34 years versus 35 - 64 years, was to maximize the number of products with significant difference between the age groups. The female participants (88 individuals) and participants of age between 35-64 accounted for more than half in the adult group (total of 149 participants). Differences in the acceptance of peanut nutrition bars were not found between male and female participants except for 50:50, 30%, which had a higher acceptance score from female participants (sample 9 in Table 2.6). Women are reported to have a higher tolerance for sour fruits (Törnwall et al., 2014), which can explain the higher acceptance, by Senegalese women for the formulation with the highest baobab level. The formulations with less than 50% cowpea in the cowpea-corn blend had a higher acceptance among participants between 35 - 64 years old compared to the younger group (samples 1, 2, and 8 in Table 2.6). Compared to younger individuals, participants between 35 - 64 years old possibly preferred a different flavor to cowpea which is a staple crop in Senegal and is used in several traditional dishes (Sciences, 2005).

The sensory acceptance of the three peanut nutrition bar formulations presented to the school age children directly depended on the ratio of cowpea flour to corn flour. The average acceptance scores for the bars decreased from 7.7 to 7.0 with increasing ratio of cowpea flour to corn flour ( $p < 0.05$ , Table 2.6). Similar results were reported by Ngoma et al. that cowpea flour levels above 30% was disliked by children (Ngoma et al., 2018).

## **Conclusion**

The development of 9 different formulations from varying levels of cowpea flour, corn flour and baobab powder allowed the prediction of a suitable formulation with texture, nutrition content and water activity desired by the target communities. The addition of acacia gum improves the cohesiveness and gumminess of formulations with low levels of baobab powder, which had the highest scores for the peanut nutrition bars in the consumer acceptance test. Vitamin A and zinc levels were however low in all formulations due to the low presence of indigenous vitamin A containing foods in the Kaffrine area and the absence (Badiane et al., 2018).

The low water activity of the peanut nutrition bars protects against bacterial spoilage however, a further reduction using other natural gums might be necessary to prevent mold growth. Kungutu (local peanut cake) having the highest scores shows the appreciation and desirability for local and familiar value added products, showing the potential for peanut nutrition bars developed by smallholder women farmers.

A suitable package developed from biodegradable local packaging materials will be necessary to improve the market potential of the peanut nutrition bars. Further studies on the shelf life of the peanut nutrition bar in and outside the developed package need to be conducted to determine shelf and structural stability for transport. The acceptance of the three primary formulations by school-age children also forms a strong basis for the adaptation of the peanut nutrition bars into the school feeding program in Kaffrine, Senegal. The higher acceptance of sample 8 over sample 6 and 7 however needs to be examined further, to adequately satisfy the sensory preferences of school-age children.

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## Tables

**Table 2.1** Coded levels and corresponding values for the peanut nutrition bar formulations generated in the response surface methodology experimental design<sup>a</sup>.

Sample number	Sample formulation	Block	Factor I		Factor II		Weight of ingredients in the formulation (g, w.b.) <sup>b</sup>		
			Coded level (X <sub>1</sub> )	Weight ratio of cowpea flour to corn flour (d.b.)	Coded level (X <sub>2</sub> )	Weight percent of baobab powder in the cowpea-corn-baobab blend (%., d.b.)	Cowpea flour	Corn flour	Baobab powder
1	25:75, 15%	1	-1	25:75	-1	15	11	33.2	7.8
2	25:75, 25%	1	-1	25:75	1	25	9.7	29.3	13
3	75:25, 15%	1	1	75:25	-1	15	33.2	11	7.8
4	75:25, 25%	1	1	75:25	1	25	29.3	9.7	13
5	50:50, 20%	1	0	50:50	0	20	20.8	20.8	10.4
6	50:50, 20%	1	0	50:50	0	20	20.8	20.8	10.4
7	100:0, 20%	2	1.414	100:0	0	20	41.6	0	10.4
8	0:100, 20%	2	-1.414	0:100	0	20	0	41.6	10.4
9	50:50, 30%	2	0	50:50	1.414	30	18.2	18.2	15.6
10	50:50, 10%	2	0	50:50	-1.414	10	23.4	23.4	5.2
11	50:50, 20%	2	0	50:50	0	20	20.8	20.8	10.4
12	50:50, 20%	2	0	50:50	0	20	20.8	20.8	10.4

a. d.b. and w.b. denotes dry base and wet base, respectively.

b. The weight of each ingredient on a wet base in the formulation was calculated to achieve the same total moisture content of the mixture across the 12 formulations.

**Table 2.2** Texture properties of the peanut nutrition bars with and without acacia gum<sup>a</sup>.

Sample number	Formulation <sup>b</sup>	Hardness		Cohesiveness	
		With	Without	With	Without
1	25:75, 15%	1135.5 ± 112.8 <sup>ef*</sup>	1644.0 ± 279.8 <sup>def*</sup>	0.058 ± 0.006 <sup>cd</sup>	0.062 ± 0.006 <sup>abc</sup>
2	25:75, 25%	1685.0 ± 131.1 <sup>bcdef*</sup>	2357.1 ± 395.6 <sup>bcd*</sup>	0.066 ± 0.01 <sup>bc*</sup>	0.052 ± 0.003 <sup>c*</sup>
3	75:25, 15%	1598.4 ± 169.9 <sup>cdef</sup>	1721.0 ± 203.5 <sup>def</sup>	0.072 ± 0.007 <sup>ab</sup>	0.063 ± 0.005 <sup>ab</sup>
4	75:25, 25%	1855.5 ± 508.5 <sup>bcde*</sup>	2771.4 ± 560.0 <sup>bc*</sup>	0.054 ± 0.004 <sup>d</sup>	0.057 ± 0.005 <sup>bc</sup>
5	50:50, 20%	2051.8 ± 557.0 <sup>bc</sup>	2007.7 ± 174.2 <sup>cd</sup>	0.058 ± 0.01 <sup>cd*</sup>	0.040 ± 0.004 <sup>d*</sup>
6	50:50, 20%	1328.4 ± 184.8 <sup>cdef*</sup>	2107.3 ± 413.1 <sup>bcd*</sup>	0.059 ± 0.016 <sup>cd</sup>	0.064 ± 0.006 <sup>ab</sup>
7	100:0, 20%	1130.1 ± 240.2 <sup>ef*</sup>	1678.2 ± 237.2 <sup>def*</sup>	0.079 ± 0.008 <sup>a</sup>	0.069 ± 0.02 <sup>a</sup>
8	0:100, 20%	1258.2 ± 176.5 <sup>def*</sup>	2582.9 ± 374.6 <sup>bc*</sup>	0.048 ± 0.01 <sup>d</sup>	0.057 ± 0.014 <sup>bc</sup>
9	50:50, 30%	2431.9 ± 380.3 <sup>b*</sup>	2828.4 ± 588.3 <sup>b*</sup>	0.056 ± 0.009 <sup>cd</sup>	0.060 ± 0.007 <sup>abc</sup>
10	50:50, 10%	1102.2 ± 139.5 <sup>ef</sup>	1010.1 ± 157.5 <sup>f</sup>	0.072 ± 0.012 <sup>ab</sup>	0.064 ± 0.008 <sup>ab</sup>
11	50:50, 20%	1711.3 ± 379.9 <sup>bcdef*</sup>	2242.0 ± 205.2 <sup>bcd*</sup>	0.058 ± 0.013 <sup>cd</sup>	0.066 ± 0.004 <sup>ab</sup>
12	50:50, 20%	1985.8 ± 300.3 <sup>bcd</sup>	1739.3 ± 300.8 <sup>de</sup>	0.056 ± 0.009 <sup>cd</sup>	0.062 ± 0.006 <sup>ab</sup>
	Kungutu	1046.5 ± 63.5 <sup>f</sup>	1046.5 ± 63.5 <sup>ef</sup>	0.034 ± 0.006 <sup>e</sup>	0.034 ± 0.006 <sup>d</sup>
	Quaker PBSS	9164.2 ± 2012.1 <sup>a</sup>	9164.2 ± 2012.1 <sup>a</sup>	0.067 ± 0.004 <sup>bc</sup>	0.067 ± 0.004 <sup>ab</sup>

- a. For the same column, values (means ± SD) followed by the same letter are not significantly different. For the same row, values with \* indicate a significant difference between the means within the same texture category based on a two-sample t-test ( $\alpha = 0.05$ ).
- b. Refer to Table 2.1 for the formulation descriptions of the peanut nutrition bars.

**Table 2.2** continued

Sample number	Formulation <sup>b</sup>	Gumminess	
		With	Without
1	25:75, 15%	66.1 ± 13.1cd*	101.5 ± 19.9cde*
2	25:75, 25%	112.1 ± 22.9bc	122.8 ± 22.8bcde
3	75:25, 15%	115.9 ± 22.5bc	108.4 ± 20.2cde
4	75:25, 25%	98.5 ± 23.6bc*	158.1 ± 34.0bc*
5	50:50, 20%	118.9 ± 34.5bc*	79.5 ± 4.2def*
6	50:50, 20%	80.2 ± 31.8bcd*	135.7 ± 31.2bcd*
7	100:0, 20%	89.8 ± 25.7bcd	115.8 ± 37.3bcde
8	0:100, 20%	60.9 ± 18.1cd*	147.9 ± 43.4bc*
9	50:50, 30%	136.4 ± 32.3b*	170.8 ± 43.2b*
10	50:50, 10%	79.4 ± 15.4bcd	64.3 ± 12.4ef
11	50:50, 20%	98.9 ± 25.7bc*	148.1 ± 10.4bc*
12	50:50, 20%	112.1 ± 26.9bc	109.4 ± 28.0cde
	Kungutu	35.8 ± 4.5d	35.8 ± 4.5f
	Quaker PBSS	163.4 ± 618.5a	163.4 ± 618.5a

a. For the same column, values (means ± SD) followed by the same letter are not significantly different. For the same row, values with \* indicate a significant difference between the means within the same texture category based on a two-sample t-test ( $\alpha = 0.05$ ).

b. Refer to Table 2.1 for the formulation descriptions of the peanut nutrition bars.

**Table 2.3** Regression coefficients for the determinations of the texture properties of peanut nutrition bars with and without acacia gum.

Parameter <sup>a</sup>	With acacia gum <sup>b</sup>			Without acacia gum		
	Hardness	Cohesiveness	Gumminess	Hardness	Cohesiveness	Gumminess
Intercept	1769.3***	0.058***	102.54***	2021.0***	0.059	119.16***
X <sub>1</sub>	101.8	-0.005**	-0.59	-113.5	0.003	-0.82
X <sub>2</sub>	311.6***	-0.004*	-5.08	547.5***	-0.002	28.62***
X <sub>1</sub> :X <sub>2</sub>	-73.1	-0.007**	-15.83*	71.4	0.001	7.03
X <sub>1</sub> <sup>2</sup>	-274.2***	0.002	-12.46*	65.5	0.001	5.33
X <sub>2</sub> <sup>2</sup>	46.7	0.002	5.82	-28.8	0.001	-1.12

- a. X<sub>1</sub> = coded level for the weight ratio of cowpea flour to corn flour; X<sub>2</sub> = coded level for the weight percent of baobab powder in the cowpea-corn-baobab blend; X<sub>1</sub>: X<sub>2</sub> = interaction of factors 1 and 2; X<sub>1</sub><sup>2</sup> = second order of factor 1; X<sub>2</sub><sup>2</sup> = second order of factor 2.
- b. Values superscripted with\*\*\*, \*\* and \* indicated that the regression was significant at P < 0.001, p < 0.01 and p < 0.05, respectively.

**Table 2.4** Nutrient profile and water activity of the peanut nutrition bar formulations with acacia gum<sup>a</sup>.

Sample number	Formulation	Nutrition profile <sup>b</sup>							Water Activity ± SD
		Energy (kcal)	Protein (g)	Fiber (g)	Calcium (mg)	Iron (mg)	Vitamin C (mg)	Folate (µg)	
1	25:75, 15%	440	8.0	9.0	450	3.0	6.41	77.9	0.771 ± 0.011 <sup>a</sup>
2	25:75, 25%	420	8.0	10	441	3.0	9.99	65.1	0.744 ± 0.004 <sup>bc</sup>
3	75:25, 15%	440	12.0	9	472	4.0	6.74	212.9	0.750 ± 0.025 <sup>abc</sup>
4	75:25, 25%	440	11.0	12	485	4.0	10.84	187.9	0.745 ± 0.014 <sup>bc</sup>
5	50:50, 20%	440	10.0	10	468	4.0	8.63	136.9	0.745 ± 0.015 <sup>bc</sup>
6	50:50, 20%	440	10.0	10	468	4.0	8.63	136.9	0.754 ± 0.011 <sup>ab</sup>
7	100:0, 20%	440	13.0	11	490	5.0	8.94	263.3	0.752 ± 0.007 <sup>abc</sup>
8	0:100, 20%	447	7.0	9	447	2.0	8.32	10.4	0.742 ± 0.014 <sup>bc</sup>
9	50:50, 30%	440	9.0	12	482	4.0	12.75	119.8	0.729 ± 0.015 <sup>c</sup>
10	50:50, 10%	440	11.0	8	454	3.0	4.51	154.0	0.771 ± 0.001 <sup>a</sup>
11	50:50, 20%	440	10.0	10	468	4.0	8.63	136.9	0.754 ± 0.016 <sup>ab</sup>
12	50:50, 20%	440	10.0	10	468	4.0	8.63	136.9	0.772 ± 0.012 <sup>a</sup>
	Quaker PBBS	525	12.6	12.6	42	2.31	-	-	0.608 ± 0.015 <sup>d</sup>
	Recommended dietary allowance	1200-1800	19-34	16.8-25.2	1000-1300	8-10	25-45	200-300	

a. The nutrient contents displayed are per 126 g of the product.

b. Refer to Table 2.1 for the formulation descriptions of the peanut nutrition bars.

**Table 2.5** Regression coefficients for the determinations of the nutrition content of peanut nutrition bars.

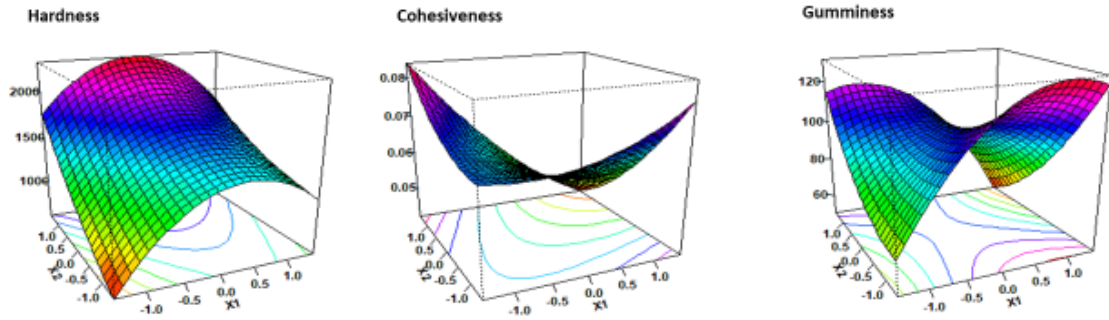
Parameter <sup>a</sup>	Nutrition profile						Water activity <sup>b</sup>	Adult sensory acceptance
	Protein	Fiber	Calcium	Iron	Vitamin C	Folate		
Intercept	10.00***	10.00***	468.00***	4.00***	8.63***	136.86***	0.756***	6.67***
X <sub>1</sub>	1.94***	0.60***	15.85***	0.78**	0.26	76.93***	-0.004	-0.17
X <sub>2</sub>	-0.48*	1.21***	5.45	0.18	2.42***	-10.78	-0.012***	-0.47*
X <sub>1</sub> :X <sub>2</sub>	-0.25	0.50**	5.50	1.39e-15	0.13	-3.06	0.005	-0.64*
X <sub>1</sub> <sup>2</sup>	-0.06	1.55e-16	-1.313	-0.25	-0.03	-0.22	-0.004	-0.28
X <sub>2</sub> <sup>2</sup>	-0.06	1.31e-16	-1.564	-0.25	-0.03	-0.22	-0.002	-0.26

- a. X<sub>1</sub> = coded level for the weight ratio of cowpea flour to corn flour; X<sub>2</sub> coded level for the weight percent of baobab powder in the cowpea-corn-baobab blend; X<sub>1</sub>:X<sub>2</sub> = interaction of factors 1 and 2; X<sub>1</sub><sup>2</sup> = second order of factor 1; X<sub>2</sub><sup>2</sup> = second order of factor 2.
- b. Values superscripted with\*\*\*, \*\* and \* indicated that the regression was significant at P < 0.001, p < 0.01 and p < 0.05, respectively.

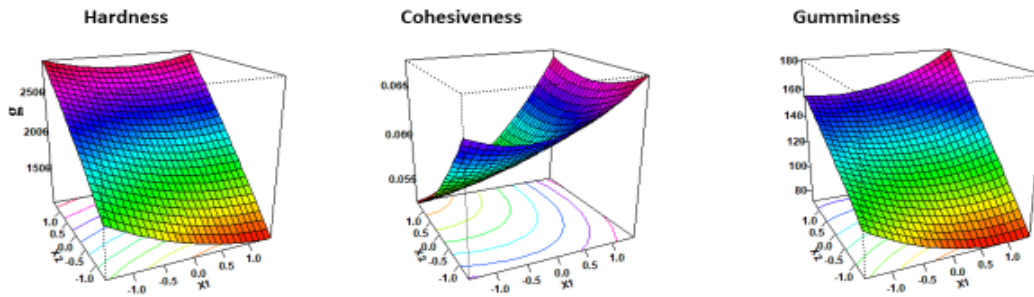
**Table 2.6** The Consumer sensory acceptance of the peanut nutrition bars<sup>a</sup>.

Sample number	Formulation <sup>b</sup>	Adult					School-age children (8 - 12 years)
		Overall	Gender		Age		
			Female	Male	18-34 years	35-64 years	
1	25:75, 15%	6.0 ± 2.8 <sup>gh</sup>	5.5 ± 2.9 <sup>ef</sup>	6.9 ± 2.7 <sup>bcde</sup>	5.6 ± 2.9 <sup>ghi*</sup>	6.0 ± 2.8 <sup>gh*</sup>	- <sup>c</sup>
2	25:75, 25%	6.3 ± 2.2 <sup>efgh</sup>	6.1 ± 2.5 <sup>de</sup>	6.7 ± 1.5 <sup>bcde</sup>	5.7 ± 2.4 <sup>fghi*</sup>	6.3 ± 2.2 <sup>efgh*</sup>	-
3	75:25, 15%	7.1 ± 2.1 <sup>cdef</sup>	7.1 ± 2.4 <sup>bcd</sup>	7.3 ± 1.7 <sup>abc</sup>	7.1 ± 2.0 <sup>bcde</sup>	7.1 ± 2.1 <sup>cdef</sup>	-
4	75:25, 25%	4.9 ± 3.0 <sup>i</sup>	4.8 ± 3.1 <sup>f</sup>	5.5 ± 2.6 <sup>def</sup>	4.7 ± 3.0 <sup>i</sup>	4.9 ± 3.0 <sup>i</sup>	-
5	50:50, 20%	7.5 ± 1.9 <sup>bcd</sup>	7.0 ± 2.1 <sup>bcd</sup>	8.0 ± 1.4 <sup>ab</sup>	6.9 ± 2.0 <sup>cdef</sup>	7.5 ± 1.9 <sup>bcd</sup>	-
6	50:50, 20%	6.5 ± 2.6 <sup>defgh</sup>	6.6 ± 2.9 <sup>cde</sup>	6.3 ± 2.3 <sup>cde</sup>	5.9 ± 2.8 <sup>efghi*</sup>	6.5 ± 2.6 <sup>defgh*</sup>	7.4 ± 2.3 <sup>ab</sup>
7	100:0, 20%	5.8 ± 3.0 <sup>hi</sup>	6.0 ± 3.0 <sup>def</sup>	5.4 ± 2.9 <sup>ef</sup>	5.7 ± 3.1 <sup>fghi</sup>	5.8 ± 3.0 <sup>hi</sup>	7.0 ± 2.2 <sup>b</sup>
8	0:100, 20%	6.5 ± 2.7 <sup>defgh</sup>	7.0 ± 2.8 <sup>bcd</sup>	6.2 ± 2.7 <sup>cde</sup>	5.8 ± 2.9 <sup>efghi*</sup>	6.5 ± 2.7 <sup>defgh*</sup>	7.7 ± 1.8 <sup>a</sup>
9	50:50, 30%	5.6 ± 2.6 <sup>hi</sup>	6.3 ± 2.8 <sup>de*</sup>	4.7 ± 2.3 <sup>f*</sup>	5.2 ± 2.4 <sup>hi</sup>	5.6 ± 2.6 <sup>hi</sup>	-
10	50:50, 10%	6.8 ± 2.5 <sup>defg</sup>	6.6 ± 2.6 <sup>de</sup>	7.1 ± 2.4 <sup>abcd</sup>	5.8 ± 2.7 <sup>fghi*</sup>	6.8 ± 2.5 <sup>defg*</sup>	-
11	50:50, 20%	6.1 ± 2.5 <sup>fgh</sup>	6.3 ± 2.4 <sup>de</sup>	6.9 ± 2.5 <sup>bcde</sup>	6.3 ± 2.5 <sup>defgh</sup>	6.53 ± 2.4 <sup>defgh</sup>	-
12	50:50, 20%	6.5 ± 2.4 <sup>defgh</sup>	6.1 ± 2.7 <sup>de</sup>	5.9 ± 1.8 <sup>cdef</sup>	6.1 ± 2.6 <sup>efgh</sup>	6.1 ± 2.5 <sup>fgh</sup>	-
	Kungutu A	8.0 ± 2.2 <sup>abc</sup>	7.8 ± 2.5 <sup>abc</sup>	8.5 ± 1.4 <sup>a</sup>	7.6 ± 2.7 <sup>abcd</sup>	8.0 ± 2.2 <sup>abc</sup>	-
	Kungutu B	8.3 ± 1.6 <sup>ab</sup>	9.0 ± 0.0 <sup>a</sup>	8.0 ± 1.8 <sup>ab</sup>	8.5 ± 1.6 <sup>a</sup>	8.3 ± 1.6 <sup>ab</sup>	-
	Kungutu C	8.5 ± 1.1 <sup>a</sup>	8.7 ± 0.9 <sup>a</sup>	8.1 ± 1.6 <sup>ab</sup>	8.4 ± 1.2 <sup>ab</sup>	8.5 ± 1.1 <sup>a</sup>	-
	Quaker PBBS A	7.0 ± 2.7 <sup>cdef</sup>	6.7 ± 2.7 <sup>cde</sup>	8.0 ± 2.2 <sup>ab</sup>	6.5 ± 3.0 <sup>cdefg</sup>	7.0 ± 2.7 <sup>cdef</sup>	-
	Quaker PBBS B	7.4 ± 2.5 <sup>bcd</sup>	8.1 ± 2.2 <sup>ab</sup>	7.0 ± 2.5 <sup>bcd</sup>	7.7 ± 2.1 <sup>abc</sup>	7.4 ± 2.5 <sup>bcd</sup>	-
	Quaker PBBS C	7.3 ± 2.1 <sup>cde</sup>	7.2 ± 2.0 <sup>bcd</sup>	7.3 ± 2.4 <sup>abc</sup>	6.8 ± 2.3 <sup>cdefg</sup>	7.3 ± 2.1 <sup>cde</sup>	-

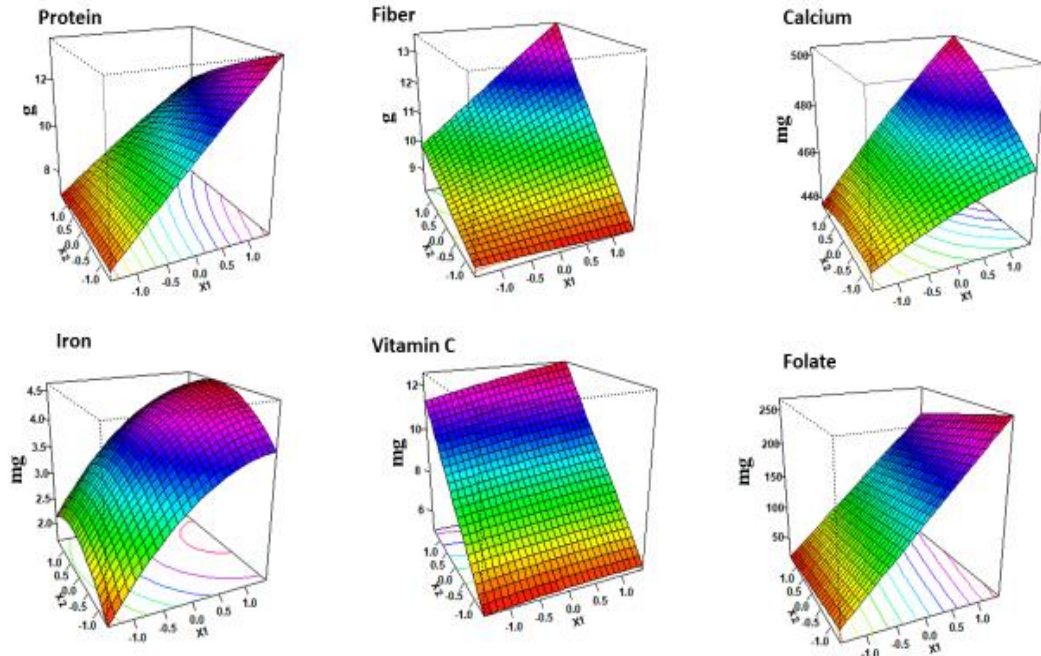
- a. For the same column, values (means ± SD) followed by the same letter are not significantly different based on Fisher's least significant difference test ( $\alpha = 0.05$ ). For the same row, values with \* indicate a significant difference between the means within the same demographic category based on a two-sample t-test ( $\alpha = 0.05$ ).
- b. Refer to Table 1 for the formulation descriptions of the peanut nutrition bars. The A, B, and C letters following Kungutu and Quaker PBBS denote the three table stations that serve the products in the sensory test.

**Figures**

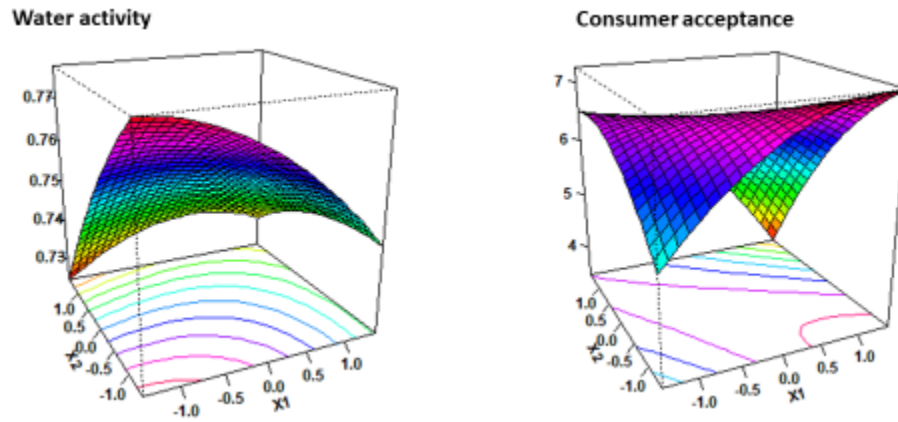
**Figure 2.1** Response surfaces showing the texture properties of the peanut nutrition bars made with acacia gum and with different levels of cowpea flour, corn flour and baobab powders.  $X_1$  and  $X_2$  are the RSM coded levels for the weight ratio of cowpea flour to corn flour, and percent baobab powder in the cowpea-corn-baobab blend, respectively (Table 2.1).



**Figure 2.2** Response surfaces showing the texture properties of the peanut nutrition bars made without acacia gum and with different levels of cowpea flour, corn flour and baobab powders.  $X_1$  and  $X_2$  are the RSM coded levels for the weight ratio of cowpea flour to corn flour, and percent baobab powder in the cowpea-corn-baobab blend, respectively (Table 2.1).



**Figure 2.3** Response surfaces showing the nutrition profiles of the peanut nutrition bars made with acacia gum and with different levels of cowpea and corn flours and baobab powders.  $X_1$  and  $X_2$  are the RSM coded levels for the weight ratio of cowpea flour to corn flour, and percent baobab powder in the cowpea-corn-baobab blend, respectively (Table 2.1).



**Figure 2.4** Response surfaces showing the water activity and adult consumer acceptance of the peanut nutrition bars made with acacia gum and with different levels of cowpea flour, corn flour and baobab powders.  $X_1$  and  $X_2$  are the RSM coded levels for the weight ratio of cowpea flour to corn flour, and percent baobab powder in the cowpea-corn-baobab blend, respectively (Table 2.1).

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