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Research Application Summary

# Substitutability of wheat flour with potato-sorghum composites for cookies production

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## Abstract

The growing demand for convenient and health oriented food products has led to production of ready-to-eat products such as cookies and biscuits with low fat and sugar contents, and appropriate mineral compositions. The objective of this study was to assess the feasibility of using potato-sorghum composite as a substitute for wheat to achieve cookies with equally competitive nutritional quality and sensory attributes. Composite blends of potato (*Solanum tuberosum* L.), sorghum (*Sorghum bicolor* L. Moench) and wheat (*Triticum aestivum* L.) flour,in the ratios of 20:10:70, 10:20:70, and 15:15:70, as well as a control with 100% wheat flour,were used to process cookies,whilemaintaining constant other ingredients namely; butter, milk, eggs, baking powder and sugar. Cookies with potato-sorghum blends exhibited less fat and high dietary fiber and protein content than the control. In addition ,mineral profiles in terms of zinc, calcium, potassium and iron showed a significant difference between the control and the cookies containing potato-sorghum composite flour.Substitution with potato-sorghum composite flours increased zinc, calcium, potassium and vitamin C levels in the cookies; whereas the concentration of iron and vitamins A, which are present mainly in sorghum, appeared to be higher when sorghum concentration was increased.There was evidence of a decline in thetrend of acceptability, especially with increasing level of sorghum flour in all the formulations. The best potato-sorghum combination was 15% sorghum, 15% potato and 70 wheat, which considerably favoured cooky quality in terms of general appearance, colour, flavor and taste. The study demonstrated that minerals/fiber-enriched cookies with high quality sensory attributescould be produced by replacing of wheat flour by 15% of potato flour and 15% sorghum.

Key words: *Solanum tuberosum, Sorghum bicolor, Triticum aestivum,* wheat flour

## Résumé

La demande croissante de produits alimentaires pratiques et axées sur la santé a conduit à la production de produits prêts à la consommation tels que des gâteaux et des biscuits à faible teneur en matière grasse et en sucre, ainsi qu'avec des compositions minérales appropriées. L'objectif de cette étude était d'évaluer la faisabilité de l'utilisation d'une combinaison de pomme de terre et de sorgho comme substitut du blé pour produire des gâteaux avec des qualités nutritionnelles et organoleptiques compétitives. Des mélanges de Farine de pomme de terre (Solanum tuberosum L.), sorgho (Sorghum Bicolor L. Moench) et ble (Tritiicum Aestivum L.), dans les ratios de 20:10:70, 10:20:70, et 15:15:70, ainsi qu'un contrôle à base de farine de blé à 100%, ont été utilisés pour faire des gâteaux, tout en gardant constant les autres composés tels que le beurre, le lait, les œufs, la poudre de cuisson et le sucre. Les gâteaux fait de mélanges de la pomme de terre et du sorgho ont présenté moins de matières grasses et des quantités fibres alimentaires et de protéines plus élevées que le contrôle. De plus, les profiles minéraux en matière de zinc, de calcium, de potassium et de fer ont été significativement différents entre le contrôle et les gâteaux a base de farine composite pomme de terre-sorgho avec des farines, ces dernier présentant un avantage significatif. La concentration de fer et de vitamines A, présentes principalement dans le sorgho, a proportionnellement augmentée dans les gâteaux composites avec la concentration de sorgho. Une baisse d'acceptabilité fut notée concernant les produits composites, en particulier avec des taux plus élevés de sorgho dans toutes les formulations. La meilleure formulation était composée de 15% de sorgho, 15% de pomme de terre et de 70% de blé, ce qui favorisait considérablement la qualité de cuisson en termes d'apparence générale, de couleur, de saveur et de goût. La présente étude a démontré que les gâteaux enrichis en minéraux et fibres avec des attributs sensoriels de haute qualité peuvent remplacer la farine de blé avec des taux de 15% de la farine de pomme de terre et à 15% de sorgho.

Mots-clés: *Solanum tuberosum, Sorgho Bicolor, Triticum Aestivum,* farine de blé

## Introduction

Cookies are crisp snacks traditionally processed from wheat (*Triticum aestivum*) flour, as the main ingredient. Insub- Saharan Africa (SSA), cookies constitute major components of the dry rations fed in many institutions such as educational and medical centres, as well as the military. Unfortunately, wheat is primarily imported from predominantly temperate countries, thus posing foreign currency challenges for many SSA countries. More recently, there are scattered introductions of wheat production in the humid tropics, particularly in the highlands areas; but these initiatives are still at their infancy. Therefore, in order to sustain production of cookies in SSA, it is imperative that close substitutions for wheat flour as the main cooky ingredient are sought among the milliard of crops locally available to farming communities.

Potato (*Solanum tuberosum*) and sorghum (*Sorghum bicolor*) are some of the starchy food rich in nutrients and considered to be one of good sources of macro- and micronutrients, and dietary fiber in SSA. Addition of various proportion of soghum and potato flour in wheat flour reportedly improves the nutritive value of final products in terms of fiber, minerals and vitamins (Manley, 2000). This may be instrumental in mitigating the sugar level in blood for diabetics and in managing weight for obese people (Preedy *et al*., 2011).Partial substitution of wheat flour by potato-sorghum composite flour can also reduce gluten content of end products, hence helpingceliac patients who still have very limited food choices (Preedy *et al*., 2011).The objective of this study was to assess the feasibility of using potato-sorghum composite flour as a substitute for wheat to achieve cookies with equally competitive nutritional quality and sensory attributes.

## Materials and Methods

Potato flour used in this study was processed from variety Rwangume, using the procedure described by Ugonna *et al*. (2013); whereas sorghum and whole wheat flour were procured from the local retailers in Kampala, Uganda. Other materials used in this study includedmilk, brown sugar, butter, baking powder, vanilla chicken and eggs; all purchasedlocally from Kampala markets.

**Processing of cookies**. Cookies were prepared from combinations of potato-sorghum composite and wheat flour in ratio of 20:10:70 (T721), 10:20:70 (T712) and 15:15:70 (T755), respectively basing on the procedure of Chandra *et al*. (2016). A control of 100% wheat flour was also included. The formulations for standard cookies, with slight modifications, had ingredients of1000 g flour, 300 g sugar, 250 g butter, 30 g baking powder, 2 eggs, 10 ml vanilla essence and 200ml milk (Chandra *et al.,* 2016). Butter and sugar were taken in a bowl and creamed to a uniform consistency. Chicken eggs and vanilla were then added to the creamed mixture, and beaten together to a uniform consistency using a whisk chrome.The flour, required amount of UHT whole milk and baking powder were added to creamed mixture and mixed for 10 minutes at medium speed, with a hand dough mixer to obtain a homogeneous mixture. The dough was rolled out into thin sheets of uniform thickness, and thencut into circular shapes using cookies cutters of 3.5cm diameter, made in hard plastic.

The oven used for baking was pre-heated to 200 °C. Then, the cut pieces were placed over a tray and transferred into rotary baking oven at 170 °C for 15–20 minutes, till baking time. The cookies were then removed from the oven, cooled to room temperature (20-25 °C), packaged in plastic tins and stored at ambient temperature for further analysis.

**Chemical and physical analysis**. The moisture, carbohydrates, protein, fat, dietary fibre, vitamins A and C, ash, as well as minerals (iron, potassium, zinc, and calcium) contents of cookies were analysed in triplicates, using the procedure as recommended by AOAC 2 (016).Cookies thickness was measured using a screw gauge, and the diameter using a Vernier caliper. The diameter was divided by the thickness to get the spread ratio. The volume of cookies was computed as the area of cookies multiplied by thickness, and was estimated using Equation 1:

$$volume = \frac{\pi}{4} d^2 t \text{ (1)} \qquad \text{Equation 1}$$

Cooky density was obtained by ratio of weight of volume as indicated in Equation 2:

$$Density\left(\frac{g}{cm^3}\right) = \frac{Mass\ of\ sample\ in\ gram}{Volume\ of\ sample\ in\ cm^3} \qquad \text{Equation 2}$$

**Sensory evaluation.** Sensory evaluation involved assessment of colour, taste, flavour, texture (crunchiness) and overall acceptability of cookies by 15 untrained panelists (n = 15), mainly students in the School of Food Technology, Nutrition and Bio-engineering, Makerere University. A nine-point hedonic scale was used for the assessment (Larmond, 1977).

**Data analysis.** Data were subjected to analysis of variance using SPSS software version 22. Homogeneous data groups were determined with the multiple comparison Tukey's test at5% level of significance.

## Results and Discussion

**Proximate composition** .The results of the proximate analysis of the cookies processed are presented in Table 1. Moisture content decreased with increase in the proportion of sorghum in the composites. With the exception of treatment T21, which had the highest concentration of potato, all composite combinations had moisture contents lower than that of the control. This may have been due to water binding capacity of the potato flour which retained higher moisture content in final products (Chandra *et al.,* 2016).

There was no significant difference in carbohydrates content of cookies, irrespective of treatments, confirming that potato and sorghum can substitute perfectly for wheat flour in bakery products without affecting the energy load of cookies. Cookiestreated with sorghum-potato composites, exhibited slightly lower fat contents than the control. This could be attributed to the fiber contents of different flours which affects the fat absorption capacity (Ben *et al.,* 2017).

There was increase in protein content with increase in sorghum-potato composite flour, especially when sorghum was predominant the potato-sorghum blend (Table 1). Similar results were obtained by Oumarou *et al*. (2005), who established that sorghum based composite flour improved the protein content of the gruels. There was also an increase in dietary fibre content in cookies with increase in sorghum-potato composite flour (Table 1). This can be attributed to the high dietary fiber content in both sorghum and potato; but also their concentration of resistant starch ( Yang *et al.,* 2016).

**Vitamins and minerals.** Changes in the vitamins and mineral contents of cookies resulting from thepartial replacement of wheat flour by potato-sorghum composite flours are shown in Table 2. Substitution with potato-sorghum composite flours increased the zinc, calcium, potassium and vitamin C levels in the cookies;whereas the concentration of iron and vitamins A, which are present mainly in sorghum, appeared to be higher when the proportion of sorghum in the composites was increased. These improvements in minerals and vitamins contents of cookies can be attributed to the nutritional composition of potato and sorghum. For instance, some varieties of sorghum are known for their considerable levels of beta-carotene (Chhikara *et al.,* 2019) which can be converted to vitamin A by the human body. Studies also indicated that sorghum is a rich source of minerals such as iron and zinc (Chhikara *et al.,* 2019). Potato is renowned source of vitamin C capable of providing up to 30% of the required daily intake, but is also rich in minerals such as potassium, iron and calcium (Tian *et al.,* 2016).

**Table 1. Proximate analysis (%) of cookies processed from wheat-potato-sorghum composite flour of different ratio mixtures**

| Treatment | Moisture | Carbohydrates | Lipids | Protein | Dietary fiber | Ash |
|---|---|---|---|---|---|---|
| Cookies-T712 | 2.76 ±0.09a | 70.64 ±0.39a | 15.70 ±0.28a | 8.92 ±0.01b | 1.89 ±0.08c | 2.49 ±0.04b |
| Cookies-T755 | 2.74 ±0.08a | 70.22 ±0.11a | 15.88 ±0.01a | 8.75 ±0.04b | 0.72 ±0.02b | 2.41 ±0.04b |
| Cookies-T721 | 3.51 ±0.04b | 70.14 ±0.13a | 16.10 ±0.07a | 8.02 ±0.02a | 0.78 ±0.10b | 2.21 ±0.06a |
| Control | 2.82 ±2.82a | 70.19 ±0.17a | 16.69 ±0.35b | 7.29 ±0.31a | 0.50 ±0.04a | 2.20 ±0.03a |

Values show mean (N=3). Figures in a column with the same superscript are not significantly different ($p > 0.05$).Treatments: Cookies-T712 70% Wheat, 10% Potato, 20% sorghum;cookies-t755 70% wheat, 15% potato, 15% sorghum;cookies-t721 70% wheat, 20% potato, 10% sorghum;control:100% wheat

**Table 2. Vitamins and minerals contents of potato-sorghum, wheat flour substituted cookies**

| Treatment | Iron (mgkg$^{-1}$) | Zinc (mg kg$^{-1}$) | Calcium (mg kg$^{-1}$) | Potassium (mg kg$^{-1}$) | Vitamin A (µgkg$^{-1}$) | Vitamin C (mg100g$^{-1}$) |
|---|---|---|---|---|---|---|
| Cookies-T712 | 20.58±0.04a | 17.88±0.69a | 143.75±3.89ab | 48.23±0.32a | 32.54±1.26d | 25.48±2.68c |
| Cookies-T755 | ND | 26.49±4.29b | 184.25±9.55ab | 103.95±0.07d | 29.59±1.59c | 22.48±0.05bc |
| Cookies-T721 | ND | 22.78±0.40b | 250.25±62.58b | 80.85±0.21c | 16.76±0.50b | 17.82±0.07a |
| Control | ND | 14.52±5.18a | 53.25±10.96a | 76.90±0.14b | 14.03±0.79a | 20.45±2.54ab |

Values show mean (N=3). Figures in a column with the same superscript are not significantly different ($p > 0.05$). Treatments: Cookies-T712 70% Wheat, 10% Potato, 20% Sorghum;Cookies-T755 70% Wheat, 15% Potato, 15% Sorghum;Cookies-T721 70% Wheat, 20% Potato, 10% Sorghum;Control:100% Wheat

**Physical characteristics of cookies**. Results on the physical characteristics of cookies processed from wheat-potato-sorghum four blends are presented in Table 3. Subsitution of wheat withpotato-sorghum composite flour resulted inadecrease in the spread ratio. The decrease was significant ($p<0.05$) when sorghum was predominant in the composite flour. This couldbe attributed to the higher protein content in the potato-sorghum composite flour compared to the control (Table 1). A similar studyby Toan and Anh (2018) established that increase in protein content in cookiesraw materiasl led to a decrease in spread ratio. Spread ratio is an important quality parameter in cookies, since it influences the texture, grain finesse, bite and overall mouth feel of the cookies (Manley, 1998).

Spread ratio is positively correlated withthe diameter or width of produt, but negatively correlated with its thickeness (Table 3). As a result, the study confirmed an increase in thickness with decrease in diameter and spread ratio. The volume of cookies varied from 8 to 15cm$^3$, with the highest value recorded in the control sample; and the lowest value inthe treatment with 20% potato flour and 10% sorghum flour. This can be attributed to the fibers present in potato sorghum composite flour, which might have affected in the structure of the matrix, thus reducing its gas retention capacity in the dough. Density was not significantly affected by the partial replacement of wheat flour with potato-sorghum composite flour, marking a positive development since density is a crutial physical property of cookies as it affects sensory attributes such as the texture and the crispness of the cookies (Manley 2000).

**Sensory evaluation**. Results of the sensory attributes of cookies processed for wheat-potato-sorghum blends are presented in Table 4. Data indicated that cookies containing 20% potato flour and 10% sorghum flour were the most acceptable along with the control treatment. At 15% level of incorporation of sorghum, all the attributes recorded relatively higher score.

General appearance, colour and flavor scores of the cookies were not significantly affected by the substitution. The colour scores of cookies with 20% sorghum flour yielded the lowest score in terms of taste, but the highest in terms of texture as compared the rest of the proportions. The score of overall acceptability reduced significantly to 5.20 with increase in the proportion of sorghum flour which gave an over-cooked taste and a more pronounced brown colour to cookies which was disliked by the panelists.

**Table 3. Physical characteristics of wheat-potato-sorghum based cookies**

| Treatment | Spread ratio | Density | Diameter (cm) | Thickness (cm) | Volume (cm$^3$) |
|---|---|---|---|---|---|
| Cookies-T712 | 3.83±0.05a | 0.68±0.01a | 3.84±0.02a | 1.00±0.01d | 10.00±1.00ab |
| Cookies-T755 | 4.35±0.03b | 0.61±0.03a | 4.18±0.01b | 0.96±0.01c | 13.00±2.00bc |
| Cookies-T721 | 4.46±0.04b | 0.63±0.05a | 3.85±0.04a | 0.86±0.01a | 8.00±0.00a |
| Control | 4.61±0.19b | 0.65±0.06a | 4.23±0.15b | 0.92±0.01b | 15.00±1.00c |

Values show mean (N=3). Figures in a column with the same superscript are not significantly different ($p > 0.05$). Treatments: Cookies-T712 70% Wheat, 10% Potato, 20% Sorghum;Cookies-T755 70% Wheat, 15% Potato, 15% Sorghum;Cookies-T721 70% Wheat, 20% Potato, 10% Sorghum;Control:100% Wheat.

**Table 4. Sensory quality of the wheat-potato-sorghum based cookies**

| Treatment | Appearance | Colour | Flavour | Taste | Texture | Overall acceptability |
|---|---|---|---|---|---|---|
| Cookies-T712 | 6.40±1.71a | 6.70±1.95a | 6.30±1.77a | 4.70±1.57a | 7.20±1.54b | 5.20±1.69a |
| Cookies-T755 | 7.30±1.25a | 7.30±0.67a | 7.10±0.88a | 7.20±0.92b | 6.60±1.57ab | 6.60±1.26ab |
| Cookies-T721 | 6.20±1.39a | 6.70±1.33a | 7.30±1.49a | 6.50±0.97b | 5.10±1.59a | 7.00±1.05b |
| Control | 6.50±1.58a | 7.00±1.05a | 7.30±1.25a | 7.50±0.97b | 7.00±1.83ab | 7.30±1.34b |

Values show mean (N=10). Figures in a column with the same superscript are not significantly different ($p > 0.05$). Treatments: Cookies-T712 70% Wheat, 10% Potato, 20% Sorghum;Cookies-T755 70% Wheat, 15% Potato, 15% Sorghum;Cookies-T721 70% Wheat, 20% Potato, 10% Sorghum; Control:100% Wheat

## Conclusions

Replacement of wheat flour proportionately by potato-sorghum composite flour improves the nutritional, physical and sensory properties of developed cookies. In particular, the protein, dietary fibers, zinc, iron, calcium and vitamin A contents increase significantly when potato-sorghum composite flour is added to the formulation. Furthermore, potato-sorghum composite flour additions also improve the physical characteristics of cookies, especially at ratios of 15% potato and 15% sorghum. Incorporation of 20% potato flour and 10% sorghum flour yields approximately similar results compared with wheat flour cookies (control) in terms of sensory attributes but with improved nutritional value (low fat, high protein and fiber content, rich in micronutrients).Results also indicated that increasing the portion of sorghum flour up to 20% in the formulation led to production of cookies of inferior physical characteristics and sensory attributes, especially in terms of taste.

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