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FULL PAPER

Development of composite biscuits made from amadumbe (*Colocasia esculenta* L. Schott) and soybean (*Glycine max* L. Merrill) and investigation of their nutritional and organoleptic properties

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Abstract

The development of more popular and nutritious amadumbe based food products such as biscuits from amadumbe may be necessary to improve its utilisation and commercialization. The aim of this study was to investigate the nutritional and organoleptic properties of amadumbe-soya composite biscuits. Biscuits were prepared by combining amadumbe and soya flours at ratios 90:10, 70:30 and 50:50. There was an increase in the crude protein content of composite biscuits when the percentage of soya was increased from 10 to 30% and then 50%. Similarly, an increase in the percentage of soya in composite biscuits gave rise to an increase in the levels of lysine in composite biscuits. The addition of soya to amadumbe improved the PDCAAS of composite biscuits to a value of 1 at 50% soya addition. The addition of soya flour to amadumbe flour also resulted in composite biscuits with an improved overall amino acid profile, mineral content, protein digestibility and PDCAAS (Protein Digestibility Corrected Amino Acid Score). The 50% amadumbe-50% soya composite biscuit was identified as having the optimum quality parameters.

1. Introduction

Colocasia esculenta (L.) Schott, mostly known as amadumbe (South Africa), taro (Pacific Islands) and cocoyam (West Africa), is a tropical tuber crop (Figure 1) often cultivated in subsistence agriculture in many regions of Africa (McEwan *et al*., 2010; Kaur *et al*., 2013). In South Africa, the amadumbe crop is cultivated in the KwaZulu-Natal, Eastern Cape, Mpumalanga and Limpopo provinces (DAFF, 2011a). It is rich in starch (70-80%), mucilage (10%) with functional properties and micronutrients such as iron, zinc, vitamin A and vitamin B2 (DAFF, 2011a; Soudy *et al*., 2014; Naidoo *et al*., 2015). The high zinc content of amadumbe makes it a suitable food for children and adults suffering from zinc deficiency (Alcantara *et al*., 2013). Furthermore, amadumbe consists of very small starch granules (1.4 to 5 µm), which makes it highly digestible and therefore suitable for the preparation of infant foods (Jane *et al*., 1992).

Figure 1. Amadumbe (*Colocasia esculenta* (L.) Schott) plants

Unlike other staple food crops such as maize and sorghum, amadumbe is still very underutilised commercially in South Africa, it is cultivated mainly in subsistence agriculture by local farmers and often sold in rural communities (DAFF, 2011b; Bvenura and Afolayan, 2015). The amadumbe crop can play an important role in alleviating food insecurity and generating income in rural communities, considering that it can survive drought conditions and requires minimal agricultural input during cultivation (Baiphethi and Jacobs, 2009; Mavengahana *et al*., 2013). The

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development of value-added amadumbe food products will boost its utilisation, thereby prompting large-scale cultivation by farmers, which will, in turn, boost income generation and food security in rural communities.

Amadumbe corms have limited proteins; complementing amadumbe with a protein-rich foodstuff such as soya will, therefore, improve the protein quality of amadumbe-based processed food products (Awasthi *et al*., 2012). Amadumbe flours have also been used as ingredients for baked products and beverages (Arenillo *et al*., 2012). Leguminous protein-rich grains such as soya is rich in essential amino acids such as lysine, which improves the moisture and flavour retention as well as the texture and digestibility of baked products (Farzana and Mohajan, 2015). Soya flour has been used successfully to fortify starch-based flours to produce composite biscuits with improved nutritional content, which were acceptable to consumers (Doxastakis *et al*., 2002; Farzana and Mohajan, 2015). The development of more popular and nutritious amadumbe based food products such as biscuits from amadumbe may be necessary to improve its utilisation and commercialisation. The purpose of this study was therefore to produce protein-rich amadumbe-soya composite biscuits as well as to investigate their nutritional and organoleptic qualities.

2. Materials and methods

2.1 Preparation of amadumbe, soya and composite flours

Amadumbe corms (Figure 2) used in the study were bought from Jozini Makhatini Research Station (KwaZulu-Natal, South Africa). Soya beans were bought from Soya Foods Company (Pty) Ltd in Bryanston, South Africa. Raw amadumbe corms were peeled using a knife and washed in running water. They were then cut into chips with a knife, washed again and dried for 16 h in an oven at 55°C. The dried corms were milled into amadumbe flour using a hammer mill (Restsch GmbH 5657 HAAN, West German, type SK-1). The flour was passed through a 250 µm sieve and then stored in large airtight zip lock bags at 4°C until it was used (Alcantara *et al*., 2013). Soya beans (1 kg) were cleaned and boiled in water at 100°C for 30 mins to ease the removal of the seed coats. After boiling, the soya beans were dehulled manually, oven-dried for 16 hrs at 55°C and milled in a hammer mill (Restsch GmbH 5657 HAAN, West German, type SK-1) to obtain flour. The soya flour was passed through a 250 µm sieve and then stored in large airtight zip lock bags at 4°C until used (Asaam *et al*., 2018). Amadumbe and soya flours were mixed in the following ratios: 90:10, 70:30 and 50:50 to have amadumbe flour as the principal component using a Kitchen Aid heavy-duty electric mixer (Model 5 KS, USA) and passed through a 250 µm sieve. Composite flours were stored in airtight zip lock plastic bags and cold-stored at 4°C until they were used (Okpala and Chinyelu, 2011).

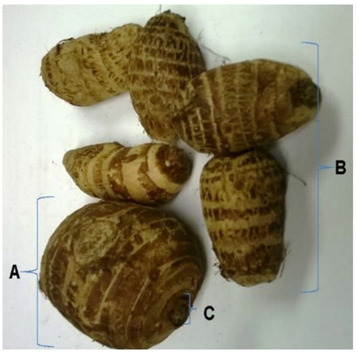

Figure 2. Amadumbe (*Colocasia esculenta* (L.) Schott) plants

2.2 Preparation of amadumbe-soya composite biscuits

The materials used for making biscuits were purchased from various supermarkets in KwaZulu-Natal, South Africa. For biscuit preparation, the basic ingredients comprised white sugar "Selati" (TSB Sugar, Malelane, South Africa), baking powder "Bokomo-Moirs" (Pioneer Foods Ltd, Cape Town, South Africa), sunflower oil "Sunfoil" (Willowton Oil, Pietermaritzburg, South Africa), water, vanilla essence. Various flours; amadumbe flour (100%) or soya flour (100%) or amadumbe-soya composite flour (90:10, 70:30 and 50:50) were used (Table 1) (Serrem *et al*., 2011). An electronic kitchen scale was used to measure the weight of each component. The dough was prepared by mixing all the dry ingredients, followed by the addition of oil and water. The dough was kneaded for 3 mins at medium speed using a heavy-duty electric dough mixer (Model 5 KS, USA) to obtain a firm dough. The dough was then manually rolled out on a steel tray and cut into circular shapes using a 4.5 cm diameter biscuit set to produce biscuit with 10 mm thickness. The cut dough pieces were transferred onto a baking tray lined with aluminium foil, placed in a preheated electric oven set at 180°C for 25 mins, and baked. After baking, biscuits were cooled down for 30 mins at ambient temperature (Serrem *et al*., 2011). Three batches of prepared biscuits were packed in medium-sized airtight ziplock bags and stored at 4°C until they were analysed.

2.3 Proximate composition analysis

The Moisture contents, crude protein contents, crude fat contents, and ash contents of samples were analysed using the methods prescribed by the Association of Official Analytical Chemists (AOAC) procedures. The moisture was determined by drying and weighing of samples as prescribed in AOAC Method 934.01. (AOAC, 2006a). The crude protein content was determined using the Dumas combustion method as prescribed in AOAC Method 934.01. (AOAC, 2006b). The crude fat content was determined by the Soxhlet extraction method as prescribed in AOAC Method 990.03 (AOAC, 2006c). The dietary fibre content of samples was determined using the enzymatic gravimetric method prescribed by the AOAC Method 985.29 (AOAC, 2006d). The total carbohydrate by difference, "Total carbohydrates = 100 – (Protein + Fat + Ash + Fibre)" was determined as prescribed in AOAC (2006e). The energy value was calculated using Atwater calorie conversion factors, based on assumptions that each gram of carbohydrate, fat and protein would yield 17 kJ (4.0 kcal), 37 kJ, (9.0 kcal) and 17 kJ (4.0 kcal), respectively. The values were expressed in kJ (Osborne and Voogt, 1978).

2.4 Protein quality analysis of amadumbe-soya composite biscuits

The in vitro protein digestibility was determined as follows: The sample (0.2 g) was weighed and 35 mL of 0.1 M phosphate buffer (pH 2), containing 1.5 mg pepsin/mL was added. The pepsin-sample mixture was incubated at 37°C for 2 hrs with continuous shaking. Digestion was stopped by adding 2 mL of 2M NaOH, and the suspension was centrifuged at 4800 rpm at 4°C for 20 mins and the supernatant discarded. The residue was washed with 15 mL of 0.1 M phosphate buffer: pH 7 and centrifuged again. The supernatant was discarded, and the residue was washed on Whatman's No 3-filter paper which contained the undigested protein residue and was folded and placed in a digestion tube and dried for 2 hrs at 80°C. The dried sample was analysed using the micro Kjeldahl method (AOAC, 1920).

$$\% \, Protein \, Digestibility = \frac{\text{Total protein} - \text{Residual protein after pepsin digestion}}{\text{Total protein}} \text{ X } 100$$

The amino acid composition of the protein extracts was determined using the Pico-Tag protocol as described by Bidlingmeyer *et al.* (1984). Sample preparation involved the hydrolysis of proteins and peptide, which was followed by the derivatisation of amino acid using the phenyl isothiocyanate (PITC) reagent. The protein in samples was hydrolysed in 6 M HCL containing 0.05% phenol at 116°C under vacuum for 24 hrs (Siwela and Amonsou, 2016). The samples (1-40 µL) were then injected into a liquid chromatograph system (UltiMate 3000 RSLCnano LC System) containing a Pico-Tag column and 254 nm fixed-wavelength detector. Two eluents, (A): 0.14 M sodium acetate/0.5 mL/l TEA (pH 6.35), and (B): 60% acetonitrile in water, were the solvent system. Amino acid scores (AAS) of samples were obtained by dividing the content of first limiting essential amino acids (histidine, threonine, lysine, tryptophan, valine, isoleucine, phenylalanine, etc.) in a test protein (mg/g) by the content of corresponding amino acid in a reference protein (mg/g) multiplied by 100 (Caire-Juvera *et al.*, 2013). The protein digestibility corrected amino acid score (PDCAAS) was calculated by obtaining the product of the AAS and protein digestibility (Anyango *et al.*, 2011).

2.5 Mineral content analysis of amadumbe-soya composite biscuits

Calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), Zink (Zn), copper (Cu), Manganese (Mn) and iron (Fe) were determined using an atomic absorption flame emission spectrophotometer (AA-6200 Shimadzu Corp. Kyoto Japan) with air acetylene flame at 722 nm. Each sample was analysed in duplicate. Quantification was accomplished by comparison with a standard curve drawn using a standard solution of known concentration at 0.5, 1.00, 1.5 and 2.5 ppm. Phosphorus (P) was determined by the flame photometric method (AOAC, 1990a). Each sample was analysed in duplicate.

2.6 Consumer acceptance of amadumbe-soya bean composite biscuits

After obtaining ethical clearance (2015/CAES/023) form the college of agriculture and life sciences ethics committee, a total of fifty individuals were screened and recruited from the Durban University of Technology campus in South Africa to constitute an untrained consumer test panel. The screening criteria included the consumption of biscuits at least once a week and the absence of food allergies. Members of the panel were told that they could withdraw from the study at any time and they were asked to sign a consent form prior to the tasting of samples. A total of 5 types of biscuits, amadumbe (100%), soya (100%) and amadumbe-soya composites (with ratios 90:10, 70:30 and 50:50), each with a 3-digit number code, were presented to each member of the panel. Each sample was tested for colour, aroma, taste, texture and overall acceptability using a 9-point hedonic scale. The nine structural acceptability levels ranged from 9 "like extremely", 8 "like very much", 7 "liked moderately", 6 "liked slightly", 5 "neither like nor dislike", 4 "disliked slightly", 3 "disliked moderately", 2 "dislike very much" and 1 "dislike extremely". Questions and scales were displayed on sensory evaluation forms (Kayitesi *et al.*, 2010).

3. Results and discussion

3.1 Proximate composition of amadumbe-soya composite biscuits

A significant decrease ($p \leq 0.05$) in the moisture content only occurred when the percentage of soya in the

Table 1. Formulation of preparation of wheat, amadumbe, soya and *amadumbe*-soya composite biscuits

Samples	Amadumbe flour (g)	Soya flour (g)	Sugar (g)	Sunflower oil (g)	Baking powder (g)	Vanilla essence (g)	Water (g)
Amadumbe flour (100%)	225 (48.7)	0	56 (12.1)	66 (14.3)	1.5 (0.3)	13.5 (2.9)	100 (21.7)
Soya (100%)	0	225 (48.7)	56 (12.1)	66 (14.3)	1.5 (0.3)	13.5 (2.9)	100 (21.7)
Amadumbe (90): soya flour (10)	202.5 (43.8)	22.5 (4.9)	56 (12.1)	66 (14.3)	1.5 (0.3)	13.5 (2.9)	100 (21.7)
Amadumbe (70): soya flour (30)	157.5 (34.1)	67.5 (14.6)	56 (12.1)	66 (14.3)	1.5 (0.3)	13.5 (2.9)	100 (21.7)
Amadumbe (50): soya flour (50)	112.5 (24.4)	112.5 (24.4)	56 (12.1)	66 (14.3)	1.5 (0.3)	13..5 (2.9)	100 (21.7)

Figures in parentheses are percentages (Serrem *et al*., 2011).

Table 2. Proximate composition of amadumbe-soya composite biscuits (g/100 g)

Variables	Flour blends (amadumbe*:* soya*) biscuits*				
	Amadumbe (100%)	Soya - 100%	Amadumbe-soya (90:10)	Amadumbe-soya (70:30)	Amadumbe-soya (50:50)
Moisture	$7.44±0.08^{bc}$	$6.07±0.24^{d}$	$8.42±0.03^{a}$	$8.22±0.08^{a}$	$6.76±0.16^{cd}$
Ash	$3.45±0.01^{a}$	$2.62±0.23^{c}$	$3.35±0.08^{a}$	$3.13±0.05^{b}$	$3.03±0.01^{b}$
Fat	$19.59±0.41^{e}$	$37.3±0.17^{a}$	$21.2±0.18^{d}$	$24.78±0.05^{c}$	$28.8±0.35^{b}$
Dietary fibre	$8.28±0.28^{e}$	$15.75±0.74^{a}$	$10.04±0.82^{d}$	$11.13±0.39^{c}$	$13.38±0.03^{b}$
Crude protein	$4.59±0.00^{f}$	$32.3±0.08^{a}$	$7.0±0.04^{e}$	$13.2±0.14^{c}$	$19.2±0.18^{b}$
Total Carbohydrates	$64.93±0.73^{a}$	$30.65±0.26^{f}$	$59.86±0.19^{c}$	$50.72±0.16^{d}$	$42.24±0.04^{e}$
Energy value (Kcal)	600.7	501.07	449.9	437.34	414.73

Values expressed as Mean ± SD and Mean within rows with the same superscript letters are not significantly different ($p \geq 0.05$), otherwise significantly different at ($p \leq 0.05$).

composite biscuits was increased from 30 to 50% (Table 2). The moisture content of biscuits is described as an indicator of dry matter in the food products (Adebowale *et al*., 2012). The moisture content of all biscuits was above 5%, higher than the recommended moisture content of 5% and lower (Patel *et al*., 2019); therefore the 50% amadumbe composite biscuit was recommended for long term storage because it had the lowest moisture content. A significant reduction ($p \leq 0.05$) in the ash content of amadumbe-soya composite biscuits occurred when the percentage of soya was increased from 10% to 30% but not significantly from 30% to 50% in the composite biscuits (Table 1). The ash content, which is inorganic residue such as mineral that remains after water and organic matter have been removed from biscuits (Omoba and Omogbemile, 2013; Perring and Tschopp, 2019), was higher in amadumbe than in soya. The 30% amadumbe composite biscuit with the highest ash is therefore recommended in order to produce biscuits with optimum inorganic residue.

The fat content of amadumbe-soya composite biscuits increased significantly ($p \leq 0.05$) with the increase in the percentage of soya in the composite from 10% to 30% and 50% (Table 2). Biscuits with high fat content have been found to possess lower density and are more liked by consumers (Biguzzi *et al*., 2015). The progressive increase in the fat content is due to soya beans being rich in oil ranging from 20-22% (Mishra and Chandra, 2012). Despite its ability to promote rancidity, fat contributes to the texture, structural integrity, lubrication and increased air incorporation in dough in the making of biscuits (Sozer *et al*., 2014). There was a significant increase ($p \leq 0.05$) in the dietary fibre contents of composite biscuits with an increase in the percentage of soya flours from 10% to 30% and then 50%. (Table 2). The consumption of biscuits with high dietary fibre content can improve colorectal health (Jin *et al*., 2019). The 50% amadumbe composite biscuit is recommended in order to produce composite biscuits with the highest level of dietary fibre content.

There was a significant progressive increase ($p \leq 0.05$) in the crude protein content of composite biscuits when the percentage of soya was increased from 10 to 30% and then 50%. Crude protein is an important macronutrient for the growth and maintenance of the body (Kayitesi *et al*., 2012). It influences food processing by trapping the starch in flour mixtures and contributes to the formation of the internal structure of biscuits (Maache-Rezzoug *et al*., 1998). The increase in protein content was expected considering that soya flour, which has a high protein content, has been used to enrich sorghum composites (Omoba and Omogbemile, 2013) and wheat composite biscuits (Farzana and Mohajan, 2015). Leguminous protein-rich grain such as soya has been used in compositing low protein foods to improve their protein quality (Awasthi *et al*., 2012). Composite biscuits with 50% amadumbe contained the highest crude protein content, and are likely to contribute more to the recommended daily protein requirements of 1.12 g/kg/day for babies up to 6 months to 0.74 g/kg/day for

Table 3. Amino acid composition of amadumbe-soya composite biscuits (mg/g protein)

Amino acids	Amadumbe (100%)	Soya (100%)	Amadumbe-soya (90:10)	Amadumbe-soya (70:30)	Amadumbe-soya (50:50)	[¥]Reference pattern
Essential						
Histidine	19.60±0.00[d]	23.69±0.66[a]	21.30±1.01[b]	21.97±0.00[bc]	21.36±0.14[c]	16
Threonine	39.22±0.00[a]	36.53±0.44[c]	38.01±1.01[b]	36.99±0.53[bc]	37.08±0.74[c]	25
Valine	47.93±0.00[a]	41.18±0.44[c]	47.53±2.22[a]	46.29±0.54[ab]	44.59±2.21[b]	40
Isoleucine	31.59±1.54[c]	40.25±0.44[a]	35.59±1.01[b]	35.75±0.00[b]	35.98±1.47[b]	31
Leucine	78.43±0.00[a]	71.06±0.66[c]	77.69±1.01[a]	75.21±0.00[ab]	74.97±1.84[b]	61
Phenylalanine	53.38±1.54[a]	47.06±1.32[c]	52.75±1.00[a]	51.59±0.54[ab]	49.01±1.10[b]	41
Lysine	30.50±0.00[c]	52.01±2.63[a]	32.65±0.00[c]	45.08±0.53[b]	49.88±1.48[a]	48
Non-essential						
Aspartic acid	127.45±1.54[a]	96.59±10.94[d]	126.35±1.00[a]	117.58±0.00[b]	112.79±3.32[c]	
Glutamic acid	106.75± 0.00[c]	157.44±11.1[a]	100.64±2.02[d]	107.07± 0.00[c]	127.66±5.52[b]	
Serine	54.47±0.00[a]	48.61± 0.88[c]	53.89±0.00[a]	52.86±0.54[ab]	51.96±0.74[b]	
Glycine	49.02±1.54[a]	38.55±1.10[d]	48.57±2.02[a]	45.04±1.07[b]	43.72±1.10[c]	
Arginine	59.91±1.54[c]	66.10±0.66[a]	60.09±3.03[c]	61.50±0.54[b]	63.50±5.90[ab]	
Alanine	42.48±1.54[a]	38.24±1.10[c]	42.38±0.00[a]	41.39±0.00[ab]	40.24±1.10[b]	
Proline	41.39±0.00[b]	46.60±1.10[b]	45.50±1.01[a]	43.18±0.00[b]	42.45±1.10[b]	
Tyrosine	38.13±1.51[a]	30.50±1.10[d]	39.86±3.03[a]	37.07±2.14[b]	34.39±2.58[c]	

Values expressed as Mean ± SD and Mean within rows with the same superscript letters are not significantly different ($p \geq 0.05$), otherwise significantly different at ($p \leq 0.05$). [¥]Reference pattern: amino acid scoring pattern of preschool-age child 3-10 years (WHO/FAO/UNU, 2007).

children up to 10 years for children (Garlick, 2006; De Oliveira Silva *et al*., 2018).

There was also a significant reduction ($p \leq 0.05$) in the carbohydrate content and energy value of amadumbe -soya composite biscuits when the percentage of soya was increased from 10% to 30% and then 50% (Table 2). Amadumbe corms are a good source of carbohydrates and energy (Kaushal *et al*., 2015). Amadumbe is noted to be good for diabetics and people with gastrointestinal disorders because it contains resistant starch, which ameliorate diabetic conditions and possesses putative cholesterol-lowering effect (Simsek and El, 2012; Himeda *et al*., 2014). The significant reduction of carbohydrates and energy was expected because of the progressive replacement of amadumbe with increasing soya percentages in the composite biscuit formulation. The carbohydrate content of flour influences food processing by acting as a good source of metabolizable energy and by assisting in the metabolism of fats (Kaushal *et al*., 2012).

3.2 The amino acid quality of amadumbe-soya composite biscuits

The major amino acids in composite biscuits are aspartic acid and glutamic acid (Table 3) due to their significant presence ($p \leq 0.05$) in amadumbe (Mbofung *et al*., 2006; Njintang *et al*., 2014). Aspartic acid and glutamic acid, which are important components of human tissues, such as blood proteins, hormones and enzymes, contribute to the proper functioning of many biological activities in the human body (Unger and Holzgrabe, 2018). Similarly, an increase in the percentage of soya in composite biscuits gave rise to a significant increase ($p \leq 0.05$) in the levels of lysine in composite biscuits (Table 3) due to its significant presence in soya. Amadumbe contains a relatively lower amount of lysine; the addition of soya to amadumbe, therefore, increases the levels of lysine in composite biscuits (Julianti *et al*., 2017). Soya beans, which are known to be a rich source of protein, have been used to complement the lysine content of lysine-limited cereal diets (Khetarpaul and Goyal, 2007).

Overall, the addition of soya flour to amadumbe flour resulted in composite biscuits with an improved amino acid profile (Table 3) and chemical score (Table 4) compared to wheat biscuits (Youssef, 2015), especially for those amino acids whose content was low in either amadumbe flour or soya flour. The amino acid score of all the composites was above the recommended reference amino acid (mg/g) (Table 3) prescribed by the WHO/FAO/UNU (2007) report for a foodstuff. Amadumbe corms have been found to contain substantial amounts of leucine, threonine, arginine, valine and phenylalanine, but have low amounts of histidine, lysine and isoleucine (Adane *et al*., 2013; Melese and Negussie, 2015). Soya was successfully used to increase the content of those essential amino acids which were low in amadumbe. The presence of adequate quantities of all amino acids in the diet enables optimal growth and proper functioning of the body (Kayitesi *et al*., 2012; Caire-Juvera *et al*., 2013). The fortification of amadumbe flour with soya has been found to maintain adequate

Table 4. Amino acid (chemical) scores of amadumbe-soya composite biscuit

Essential amino acids	Amadumbe (100%)	Soya (100%)	Amadumbe-soya (90:10)	Amadumbe-soya (70:30)	Amadumbe-soya (50:50)
Histidine	1.23±0.01^{e}	1.47±0.01^{e}	1.34±0.01^{d}	1.37±0.01^{c}	1.40±0.01^{b}
Threonine	1.57±0.01^{a}	1.46±0.01^{d}	1.52±0.01^{b}	1.48±0.01^{c}	1.48±0.01^{c}
Valine	1.20±0.01^{a}	1.03±0.01^{d}	1.19±0.01^{a}	1.16±0.01^{b}	1.11±0.01^{c}
Isoleucine	1.02±0.01^{d}	1.30±0.01^{a}	1.05±0.01^{c}	1.15±0.01^{b}	1.16±0.01^{b}
Leucine	1.29±0.01^{a}	1.16±0.01^{d}	1.27±0.01^{b}	1.23±0.01^{c}	1.23±0.01^{c}
Phenylalanine	1.30±0.01^{a}	1.15±0.01^{d}	1.29±0.01^{a}	1.26±0.01^{b}	1.20±0.01^{c}
Lysine	0.64±0.01^{e}	1.08±0.01^{a}	0.68±0.01^{d}	0.94±0.01^{c}	1.04±0.01^{b}

Values expressed as Mean ± SD and Mean within rows with the same superscript letters are not significantly different ($p \geq 0.05$), otherwise significantly different at ($p \leq 0.05$).

Table 5. Protein digestibility and protein digestibility corrected amino acid score (PDCAAS) amadumbe-soya biscuits

Flours	Protein digestibility (%)	Limiting amino acid chemical score	PDCAAS
Amadumbe (100%)	96	Lysine (0.64)	0.61
Soya (100%)	99	Valine (1.03)	1.02
Amadumbe-soya (90:10)	97	Lysine (0.68)	0.66
Amadumbe-soya (70:30)	98	Lysine (0.94)	0.92
Amadumbe-soya (50:50)	99	Lysine (1.04)	1.03

levels of heat-sensitive amino acids such as lysine, arginine and histidine (Obadina *et al*., 2016). The addition of soya resulted in composite biscuits with improved protein quality which, in turn, enhances their ability to support optimal growth in humans (De Oliveira Silva *et al*., 2018).

Regarding protein digestibility and PDCAAS, lysine was found to be the limiting amino acid for amadumbe biscuits and amadumbe-soya composite biscuits, while valine was the limiting amino acid for the soya biscuits. The increase in the percentage of soya resulted in a small increase in the in vitro protein digestibility of composite biscuits up to a value of 0.99 at 50% soya bean addition (Table 5). Protein digestibility, which is an estimate of the amount of protein that can be absorbed into the body from a protein diet (Okpala and Chinyelu, 2011), was higher in 100% soya biscuits than in 100% amadumbe biscuits. The lower protein digestibility of 100% amadumbe biscuits could be due to the presence of anti-nutritional factors such as phytic acids, which could have connected with protein to form a protein-mineral complex that can inhibit the activities of the protein-degrading enzyme (Rathi *et al*., 2004; Soudy *et al*., 2014). The 50% amadumbe and 50% soya composite flour had the highest digestibility values and are therefore recommended to produce amadumbe composite biscuits with the most protein digestibility.

The addition of soya to amadumbe improved the PDCAAS of composite biscuits to a value of 1 at 50% soya addition (Table 5). The PDCAAS measures the quality of protein in terms of its available indispensable amino acid content and its digestibility (Dabbour and Takruri, 2002; Vilakati *et al*., 2015). The PDCAAS increased slightly with an increase in the percentage of

Table 6. Mineral composition of amadumbe-soya composite biscuits

Mineral	Amadumbe (100%)	Soya (100%)	Amadumbe-soya (90:10)	Amadumbe-soya (70:30)	Amadumbe-soya (50:50)
Ca (g/100 g)	0.08±0.00^{d}	0.15±0.00^{a}	0.09±0.00^{c}	0.10±0.00^{a}	0.11±0.01^{a}
Mg (g/100 g)	0.05±0.00^{e}	0.13±0.01^{a}	0.06±0.00^{d}	0.08±0.00^{c}	0.09±0.01^{b}
K (g/100 g)	1.20±0.03^{a}	0.54±0.01^{d}	1.13±0.01^{a}	0.99±0.13^{b}	0.79±0.13^{c}
Na (g/100 g)	0.14±0.01^{a}	0.09±0.01^{d}	0.12±0.00^{b}	0.11±0.01^{bc}	0.11±0.00^{bc}
K/Ca^{+}Mg (g/100 g)	3.74±0.11^{a}	0.78±0.01^{f}	3.07±0.03^{b}	2.19 ±0.04^{c}	1.60±0.16^{d}
P (g/100 g)	0.17±0.00^{e}	0.44±0.00^{a}	0.19±0. 00^{d}	0.25±0.01^{c}	0.30±0.01^{b}
Zn (mg/kg)	4.00±0.00^{f}	30.0±0.00^{a}	9.00±0.00^{e}	13.0±0.00^{d}	17.00±0.00^{c}
Cu (mg/kg)	1.00±1.41^{c}	6.50±0.71^{a}	0.75±0.36^{c}	2.00±0.00^{bc}	4.00±1.41^{b}
Mn (mg/kg)	2.00±0.00^{e}	23.0±0.00^{a}	4.75±1.06^{d}	11.0±0.00^{c}	14.00±1.41^{b}
Fe (mg/kg)	24.0±2.83^{c}	38.0±0.00^{b}	26.0±0.00^{c}	32.0±1.41^{b}	38.00±2.83^{bc}

Values expressed as Mean ± SD and Mean within rows with the same superscript letters are not significantly different ($p \geq 0.05$), otherwise significantly different at ($p \leq 0.05$).

Table 7. Consumer acceptability of amadumbe-soya composite biscuits (N = 50)

Biscuits	Colour	Aroma	Taste	Texture	Overall acceptability
Amadumbe (100%)	6.96±1.80^{ab}	6.86±1.77^{a}	6.52±1.98^{ab}	6.02±2.08^{a}	6.24±1.95^{a}
Soya (100%)	7.60±1.83^{a}	6.48±1.99^{a}	6.36±1.87^{a}	6.74±1.97^{b}	6.28±2.19^{a}
Amadumbe-soya (90:10)	6.90±1.72^{ab}	6.70±1.79^{a}	6.44±2.03^{b}	6.00±2.07^{a}	6.52±1.92^{a}
Amadumbe soya (70:30)	6.70±2.14^{b}	6.72±1.77^{a}	6.62±1.82^{ab}	6.32±1.85^{a}	6.50±2.00^{ab}
Amadumbe-soya (50:50)	7.26±1.68^{ab}	6.96±1.71^{a}	7.20±1.43^{b}	6.70±1.88^{ab}	6.88±1.86^{b}

Values expressed as Mean ± SD and Mean within rows with the same superscript letters are not significantly different ($p \geq 0.05$), otherwise significantly different at ($p \leq 0.05$). Hedonic scale: 9 "like extremely", 8 "very much", 7 "like moderately", 6 "like slightly", 5 "neither like nor dislike", 4 "dislike slightly", 3 "dislike moderately", 2 "dislike very much" and 1 "dislike extremely".

soya in composite biscuits, thereby ensuring that adequate amounts of the essential amino acid, such as lysine, are present in amadumbe composite biscuits (Shaheen *et al*., 2016). Soya has been used elsewhere to improve protein digestibility and PDCAAS sorghum biscuits (Serrem *et al*., 2011). The 50% amadumbe composite is recommended to produce biscuits with PDCAAS close to 1.

3.3 Mineral analysis of amadumbe-soya composite biscuits

There was an increase in the content of Ca, Mg, P, Zn, Cu, Mn and Fe in composite biscuits when the percentage of soya in the composite biscuits was increased. The increase in the mineral content was only significant ($p \leq 0.05$) for Mg P, Zn, Mn and K. However, there was a decrease in the content of K and Na in composite biscuits when the percentage of soya was increased (Table 6). There was an increase in the amounts of Fe, Zn and Mn Fe in 100% soya biscuits, which was expected since soya beans have been found to contain a substantial amount of these minerals (Gharibzahedi and Jafari, 2017). Amadumbe corms have also been found to contain substantial amounts of K and Fe (Mergedus *et al*., 2015; Arici *et al*., 2016). Most minerals, especially Na and K, are important in maintaining the osmotic balance of the fluids in the body (Mergedus *et al*., 2015), as well as controlling the absorption of glucose and many other compounds in the body (Omoba and Omogbemile, 2013). As reflected in the total ash values, the addition of soya flour to amadumbe flour resulted in composite biscuits with improved amounts of individual minerals, especially those that were lacking in either amadumbe flour or soya flour. None of the composite biscuits possessed an outright higher amount of mineral.

3.4 Consumer acceptance of amadumbe-soya composite biscuits

An increase in the percentage of soya in the amadumbe composite biscuits did not produce any significant difference ($p \geq 0.05$) in the acceptability of the colour, aroma, taste, texture and overall acceptability of composite biscuits (Table 7). Hence, all the composite biscuits possessed desirable sensory properties (Yadav *et al*., 2012) and any of them could be used to produce amadumbe composite biscuits.

4. Conclusion

An increase in the percentage of soya in the formulation produced biscuits with a significant decrease in moisture, ash content, carbohydrate content and energy of amadumbe-soya composite biscuits. Conversely, an increase in the percentage of soya in the formulation produced composite biscuits with an increase in crude protein and lysine content of amadumbe-soya composite biscuits. The addition of soya flour to amadumbe flour resulted in composite biscuits with an overall improved amino acid profile, especially in those amino acids whose content was low in either amadumbe flour or soya flour. The addition of soya to amadumbe improved the protein digestibility and the PDCAAS of the composite biscuits. The addition of soya flour to amadumbe flour resulted in composite biscuits with improved amounts of individual minerals, especially those that were low in either amadumbe flour or soya flour. There was no significant difference in consumer response to the colour, aroma, taste, texture and overall acceptability of the different formulations of composite biscuits. The 50% amadumbe-50% soya composite biscuit was identified as having the optimum quality parameters. We recommend the usage of the 50% amadumbe-50% soya formulation to produce amadumbe biscuits with optimal nutritional and organoleptic properties.

Conflict of Interest

The authors declare no conflict of interest.

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