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Assessment of nutritional characteristics of products developed using soybean (*Glycine max* (L.) Merr.) pipeline and improved varieties

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Abstract: Breeding new varieties can introduce compositional differences in Soybean grains which could be caused by environment and climate factors, among other factors. Thus, there was need to evaluate these differences and also to investigate the applications of these varieties for product development at household level for improve nutrition. This study evaluated the nutritional, functional and pasting properties of pipeline and improved soybean varieties and of soy-based products. A total of six improved/pipeline soybean varieties and nine products were developed, which include six soy-fortified products using 80:20 wheat: soy flour blend and three soy-based products using 100% processed soybean grains, were milled and analysed. The moisture, fat and protein contents ranged from 4.91–6.13/100 g; 13.77–19.82/100 g and 31.78–36.56/100 g fresh weight, respectively. The lowest water absorption capacity (WAC) was observed for D.AL/Z 7 having 180.43% while D.AL/Z 8 had the highest value at 285.94%. Pasting viscosity ranged from 1.65–9.63 RVU. The results also showed that the ash, fiber and fat contents of Soy yoghurt are significantly ($p < 0.05$) lower compared with Soy tofu and Salad cream. Soy Tofu had a significant ($p < 0.05$) higher level of protein content (30.7/100 g FW).

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Emmanuel Oladeji Alamu, a Nigerian, is a Food Scientist and Technologist working with the International Institute of Tropical of Agriculture (IITA), Zambia. He holds a doctorate degree in Food Chemistry with over 12 years of research experience and strong analytical skills in food science and nutrition, and experienced in carrying out nutrition-sensitive agricultural research using different tools and techniques. He has many publications in local and foreign journals to his credit. Specifically, his research lines primarily examined: the physical and bioactive characteristics of biofortified and non-biofortified crops such as soybean, maize, cowpea, cassava, yam; retention studies on the bioactive compounds in unprocessed and processed biofortified crops and foods; anti-oxidant activities/capacities of unprocessed and processed biofortified crops; bioavailability and bioefficacy of processed biofortified crops and associated products; sensory characteristics of products from biofortified crops.

PUBLIC INTEREST STATEMENT

There are new soybean varieties developed by the Scientists that were better than those already found in the local markets. These varieties need to be tested to establish their nutrients and suitability for product development for home consumption. This study aimed to establish the nutrients in these new soybean varieties and use them to make some nutritious products to be consumed at the home. Considering the nutritional and cooking properties results from this study there is an indication that these varieties could be adapted locally for product development and serves as raw materials for food industries. The developed soybean-based products can provide adequate nutrients the body needs and could be used to address the problem of malnutrition, especially among mothers, pregnant women and children.

Subjects: Agriculture & Environmental Sciences; Botany; Nutrition; Food Additives & Ingredients; Food Chemistry

Keywords: soy-products; nutritional properties; soy-bread; soy-cake; soy flour

1. Introduction

Soybean (*Glycine max* L.) is a legume that grows in the tropical, subtropical and temperate climates. It is particularly known for its high protein content and is a staple in several developing countries especially in Southern Africa where it is popularly grown (Igbabul, Adole, & Sule, 2013; KeShun, 1997; Nti, Plahar, & Annan, 2016). In recent times, it has become a cash crop which small holder farmers now rely on for income partly due to an expansion of poultry and animal feed industry (Kananji et al., 2013), and also its increasing preventive therapeutic role in combating diseases (Ogundele, Ojubanire, & Bamidele, 2015; Sugano, 2006). The past five years has witnessed a release of new varieties in Zambia (International Institute of Tropical Agriculture [IITA], 2015). It is well established that breeding new soybean varieties can introduce compositional differences (Akparobi, 2009; Vasconcelos et al., 2006; Vollmann, Fritz, Wagentristl, & Ruckenbauer, 2000; Zeller, 1999), thus the need to evaluate these differences and also to investigate the usage of these new varieties at household level for improve nutrition. Furthermore information on the nutritional and physicochemical properties of improved soybean cultivars and soy-based products from Zambia is scanty. The study therefore aimed to evaluate the nutritional, functional and pasting properties of improved and pipeline Soybean varieties and also to develop soy-based products and establish their nutritional properties.

2. Materials and methods

2.1. Source of materials

Four pipelines (D.AL/Z 9, D.AL/Z 6, D.AL/Z 7, D.AL/Z 8) and Two improved varieties (TGX 1740-2F, TGX 1940-6F) used for this research work,were obtained from the research farms of IITA, Southern Africa Research Hub (SARAH), Lusaka, Zambia. The pipeline varieties are those that are under breeding evaluation for final released but the improved ones are the varieties already released to farmers. TGX 1740-2F has been released as “Kafue” in Zambia and as “Tikolore” in Malawi but TGX 1940-6F as “Mwembeshi” in Zambia.

2.2. Methods

2.2.1. Processing of soy bean grains into flour

Soy bean grains were processed into flour using the method described elsewhere by Alamu, Maziya-Dixon, Popoola, Gondwe, and Chikoye (2016).

2.2.2. Development and production of soy-fortified and soy products

A total of nine products were developed using adapted methods described by Sanni et al. (2006). The products include 6 soy-fortified products using 80:20 Wheat: Soy flour blend and three soy-based products using 100% processed soybean grains. For the preparation of each of the soy-fortified products, the wheat flour (80%) was thoroughly mixed, using Kenwood hand-held mixer, with the soy flour(20%) for 2 min before the addition of other ingredients. The adapted recipes used are described as follows:

2.2.2.1. Soy-fortified Cookies

Ingredients: Wheat flour—200 g; Soy flour—40 g; Baking powder—5 g; Sugar—50 g; Margarine—100 g and Water—60 ml.

Method: All the ingredients were mixed together in a Kenwood mixer to form a non-sticky smooth dough. The dough was then placed on a floured board, rolled to ¾ inch thickness and cut into shapes. The cut dough was placed on greased baking sheet and baked in a pre-heated oven at 120°C for 30 min.

2.2.2.2. Soy-fortified muffins
Ingredients: Wheat flour—200 g; Soy flour—40 g; Sugar—50 g; Vegetable oil—80 ml; Egg—1 medium; Baking powder—15 g and Water—125 ml.

Method: The soy and wheat flours were sieved (0.5 mm sieve size) together. Other dry ingredients (baking powder and sugar) were added to the sieved flour and thoroughly mixed. The egg, vegetable oil and water were mixed together in a separate bowl. The liquid mixture was then added to the dry ingredient and thoroughly mixed until free of lumps. The resulting batter was scooped into muffin cups and baked in a pre-heated oven at 120°C for 25 min.

2.2.2.3. Soy-fortified chin-chin
Ingredients: Wheat flour—400 g; Soy flour—80 g; Margarine—40 g; Baking powder—10 g; Eggs—2 medium; Water—225 ml; Vegetable oil—750 ml.

Method: The dry ingredients (flour, sugar, baking powder) and margarine were combined and mixed together in a Kenwood mixer. The eggs were whisked until light and added to the mixture. Lastly, water was added to form a smooth dough that leaves the sides of the mixing dough clean. The dough was rolled on a floured board, cut into designed size and deep-fried in hot oil until golden brown.

2.2.2.4. Soy-fortified pancakes
Ingredients: Soy flour—80 g; Wheat flour—400 g; Sugar—30 g; Egg—1 medium; Water—225 ml; Vegetable oil—60 ml.

Method: All ingredients were mixed together to form batter with flow consistency without lump. A non-stick frying pan was then greased with ½ teaspoon of vegetable oil at a time. The oil was heated on low heat and ½ cup of the batter was scooped into the oil and allowed to spread. The batter was fried on both sides until slightly brown.

2.2.2.5. Soy-fortified cake
Ingredients: Wheat flour—400 g; Soy flour—80 g; Margarine—400 g; Sugar—200 g; Eggs—6 medium; Baking Powder—10 g.

Method: The margarine and sugar was creamed to get her in a Kenwood mixer at high speed until fluffy before adding the eggs. The soy flour, wheat flour and baking powder were thoroughly mixed together before folding into the creamed sugar and margarine. The batter was poured into paper-cake cups placed in pans and baked at 170°C for 30 min.

2.2.2.6. Soy-fortified bread
Ingredients: Wheat flour—400 g; Soy flour—80 g; Margarine—40 g; Sugar—30 g; Instant yeast—10 g; Salt—10 g Water—750 ml.

Method: All the ingredients except margarine were mixed together in a Kenwood mixer. Water was gradually added to form dough. The dough was kneaded until smooth and shiny, cut into shape put in a greased pan and placed in a warm area for 45 min to proof. The proofed dough was then baked in a pre-heated oven at 180°C until the crust became brown.

2.2.2.7. Soy yoghurt
Ingredients: Soy milk—500 ml; Existing yoghurt—50 ml; Sugar—30 g; Salt—1 g.

Method: Salt and sugar were added to the soy milk and the mixture heated to 45°C . The existing plain yoghurt was added; the mixture was thoroughly mixed and kept in a warm place for 12 h.

2.2.2.8. Soy tofu
Ingredients: Soybean—1 kg; Water—500 ml; White vinegar (coagulant)—50 ml.

Method: The soybean grains were soaked in water overnight. The soaked grains were rinsed and blended with water using a Philips blender (HR2100/01). The resulting slurry was sieved with a chiffon cloth to obtain the milk. The milk was boiled for 20 min, removed from heat and coagulant added to curdle the milk. The curd was then poured into a tofu box lined with a muslin cloth. The sides of the muslin cloth were folded over the curd and a heavy weight placed on it for 30 min to drain off the water to obtain tofu. The tofu was then cut into desired shapes.

2.2.2.9. Tofu salad dressing
Ingredients: Tofu—125 g; Vegetable oil—30 ml; Sugar—40 g; Vinegar—30 ml; Salt—1.25 g.

Method: All the ingredients were combined together in a food blender (Philips model) and blended until smooth and creamy.

All the products samples were dried with stainless convectional oven at 50–60°C and both the clean soy grains were milled, using Laboratory mill 310 (Perten Instruments NA, Inc., Hägersten, Sweden) using sieve size 0.5 mm. They were packed in the polythene whirl- pack and stored at 4°C prior analysis. All the chemicals used for analysis were of analytical grade

2.2.3. Determination of proximate composition
All the samples (milled soy grains and soy-based products) were analyzed for moisture, protein, fat, ash, crude fiber, total sugars, starch and amylose using the methods described by AOAC (2005) and Alamu, Maziya-Dixon, Menkir, Olaofe, and Irondi (2015).

2.2.4. Determination of pasting properties
Pasting characteristics was determined with a Rapid Visco Analyser (RVA), (model RVA 4500, Perten Instruments NA, Inc., Hägersten, Sweden). Peak viscosity, trough, breakdown, final viscosity, set back, peak time, and pasting temperature were read from the pasting profile with the aid of Thermocline for Windows version 3 (TCW3) software interfaces with personal computer for viscometric data acquisition and analysis.

2.2.5. Determination of functional properties
Water absorption capacity (WAC): One gram of the sample was added to 15 ml distilled water in a pre-weighed centrifuge tube. The tube with its content was agitated on a flask Gallenkamp shaker for 2 min and centrifuged at 4,000 rpm for 20 min on a Sorvall glc-1 table top centrifuge (model 06470, USA). The amount of water bound by the flour was determined by difference and expressed as the weight of water bound by 100 g dry flour (Alamu, Maziya-Dixon, Okonkwo, & Asiedu, 2014).

Swelling power and solubility: This was determined by the Leach et al. (1959) method. It involved weighing 1 g of milled sample into 100 ml conical flask, 15 ml of distilled water was added and mixed gently at low speed for 5 min. The slurry was heated in a thermostated water bath (Thelco model 83, USA) at 80°C for 40 min. During heating, the slurry was stirred gently to prevent dumping of the starch. The content was transferred into a pre-weighed centrifuge tube and 7.5 ml distilled water was added. The tubes containing the paste were centrifuged at 2,200 rpm for 20 min using Sorvall glc-1 table top centrifuge (model 06470, USA). The supernatant was decanted immediately after centrifuging into a pre-weighed can and dried at 100°C to constant weight. The weight of the sediment and weight of soluble were taken and recorded.

Water binding capacity: This was determined using the method described by Alamu et al.(2014) and this involved weighing of 2.5 g of each sample into a tarred 50 ml centrifuge tube. 3.7 ml of distilled water was added and the tube was capped and agitated on a wrist action shaker for 1 h.

Centrifuge for 10 min at 2,200 g or approximately 7,500 rpm and decanted the water. The centrifuge tube content was weighed and the amount of water bound was calculated.

Bulk density: The bulk density of the milled samples was determined using the method described by Wang and Kinsella (1976). A known amount of each sample was weighed into a 25 or 50 ml measuring cylinder. The sample was packed by gently tapping the cylinder on the bench top 10 times and the volume was recorded . The bulk density(g/ml) was calculated using the weight and the volume.

2.2.6. Statistical analysis

The mean, Standard deviation and Coefficient of Variance of the values were calculated using Statistical Package for Social Scientists (SPSS) vs. 20. Significant means were separated using Duncan's Multiple Range Test at 95% confidence level.

3. Results and discussion

3.1. Chemical, functional and pasting properties of improved soybean varieties

The proximate composition and functional properties of the improved and pipeline soybean varieties released in Zambia are as shown in Tables 1 and 2. The moisture contents ranged from 4.91–6.13 g per 100 g fresh weight with variety TGX 1740-2F having the highest value, while variety D.AL/Z 6 having the lowest value.The highest value for ash content was recorded for TGX 1740-2F while the lowest was for the D.AL/Z 7. The fat content of the varieties show a wide variation, ranging from 13.77–19.82/100 g but variety D.AL/Z 6 had the highest fat content (19.87/100 g). This pattern of variation was also observed for the starch content of all the varieties. TGX 1940 6F had the lowest values for the amylose, sugar and starch contents among all of the varieties . The protein contents ranged from 31.78–36.56/100 g. However, varieties D.AL/Z 6 and D.AL/Z 9 had the highest fat and protein contents among the varieties studied (Table 1).The lowest water absorption capacity (WAC) was observed for D.AL/Z 7 having 180.43% while D.AL/Z 8 had the highest value at 285.94%. The water binding capacity (WBC) values ranged from 197.91 to 252.71% with D.AL/Z 7 and TGX 1940-6F having the lowest and highest value, respectively. The bulk density of the soybean varieties ranged from 0.69 to 1.01 g/ml. Solubility ranged from 10.77–11.88% with D.AL/Z 8 having the lowest value and D.AL/Z 6 the highest value. Dispersibility was lower in the TGX 1740-2F and D.AL/Z 6 varieties with their values being 30%, while the highest was D.AL/Z 8 which had a dispersibility of 60%.The pasting properties of the local and improved Soybean varieties are presented in Table 3. Peak 1, which signifies the initial viscosity showed a very wide range from 1.65–9.63 RVU, with D.AL/Z 7 and D.AL/Z 8 having the highest and TGX 1740-2F having the lowest value of 1.65 RVU. The pasting temperature varied slightly amongst the varieties. The highest temperature of 50.53°C was recorded in D.AL/Z 7 and D.AL/Z 8 while the lowest 48.89°C was observed in TGX 1940 6F.

Table 1. Proximate composition of improved and pipeline soybean varieties from Zambia in g per 100 g fresh weight

Sample parameters (g)	Moisture	Ash	Fat	Amylose	Sugar	Starch	Protein	Crude fibre
D.AL/Z 9	5.10 ± 0.09^{a}	4.71 ± 0.01^{b}	19.43 ± 0.19^{cd}	2.65 ± 0.12^{b}	10.82 ± 0.03^{b}	16.72 ± 0.15^{bc}	34.57 ± 0.17^{c}	5.84 ± 0.07^{ab}
D.AL/Z 6	4.91 ± 0.10^{a}	4.36 ± 0.01^{a}	19.82 ± 0.13^{d}	2.01 ± 0.06^{a}	9.63 ± 0.03^{a}	14.14 ± 0.58^{abc}	35.56 ± 0.66^{d}	5.45 ± 0.00^{a}
D.AL/Z 7	4.97 ± 0.08^{a}	4.25 ± 0.03^{a}	18.97 ± 0.05^{cd}	2.43 ± 0.06^{ab}	10.91 ± 0.03^{bc}	17.65 ± 0.00^{c}	33.69 ± 0.49^{b}	5.42 ± 0.23^{a}
D.AL/Z 8	5.45 ± 0.20^{b}	4.58 ± 0.03^{b}	18.00 ± 0.06^{c}	2.01 ± 0.06^{a}	9.87 ± 0.00^{a}	13.46 ± 0.00^{ab}	32.49 ± 0.05^{a}	6.10 ± 0.01^{b}
TGX 1740-2F	6.13 ± 0.10^{d}	5.91 ± 0.04^{d}	13.77 ± 0.63^{a}	2.18 ± 0.32^{ab}	11.47 ± 0.74^{bc}	14.38 ± 0.12^{abc}	32.09 ± 0.20^{a}	6.17 ± 0.04^{b}
TGX 1940 6F	5.81 ± 0.14^{c}	5.04 ± 0.18^{c}	15.40 ± 1.17^{b}	2.65 ± 0.22^{b}	11.82 ± 0.33^{c}	12.77 ± 2.99^{a}	31.78 ± 0.42^{a}	6.23 ± 0.43^{b}
Min	4.91	4.25	13.77	2.01	9.63	12.77	31.78	5.42
Max	6.13	5.91	19.82	2.65	11.82	17.65	36.56	6.23
Mean	5.40	4.81	17.56	2.32	10.75	14.85	33.53	5.87
CV (%)	9.14	12.67	13.90	12.84	8.03	12.88	5.42	6.15

Note: Means with different letters along columns are significantly different at $p < 0.05$.

Table 2. Functional properties of improved and pipeline soybean varieties from Zambia

Sample parameters	WAC (%)	WBC (%)	Bulk Density(g/ml)	Solubility (%)	Dispersibility (%)
D.AL/Z 9	217.3 ± 0.40[ab]	214 ± 3.64[a]	0.81 ± 0.01[b]	10.83 ± 0.01[b]	60.00 ± 0.00[d]
D.AL/Z 6	249.4 ± 12.00[ab]	239.7 ± 21.73[bc]	0.87 ± 0.01[cd]	11.88 ± 0.01[e]	30.00 ± 0.00[a]
D.AL/Z 7	180.43 ± 4.9[a]	197.91 ± 7.45[a]	0.82 ± 0.03[bc]	11.64 ± 0.02[d]	50.00 ± 14.14[c]
D.AL/Z 8	285.94 ± 117.9[b]	217.99 ± 0.76[ab]	0.69 ± 0.01[a]	10.77 ± 0.01[a]	60.00 ± 0.00[d]
TGX 1740-2F	238.94 ± 33.5[ab]	203.55 ± 12.45[a]	0.94 ± 0.01[d]	11.06 ± 0.01[c]	30.00 ± 0.00[a]
TGX 1940 6F	259.5 ± 5.40[ab]	252.71 ± 10.16[c]	0.94 ± 0.05[d]	11.01 ± 0.04[c]	40.00 ± 0.00[b]
Min	180.43	197.91	0.69	10.77	30.00
Max	285.94	252.71	0.94	11.88	60.00
Mean	238.58	220.97	0.85	11.20	45.00
CV(%)	15.27	9.60	11.09	4.05	30.63

Notes: Means with different letters along columns are significantly different at $p < 0.05$.
WAC = Water absorption Capacity, WBC = Water Binding Capacity, CV = Coefficient of variation.

Table 3. Pasting properties of improved and pipeline soybean varieties from Zambia

Sample parameters	Peak 1 (RVU)	Trough 1 (RVU)	Breakdown(RVU)	Final Visc (RVU)	Setback (RVU)	Peak time (RVU)	Pasting temp (RVU)
D.AL/Z 9	2.25 ± 0.00[a]	2.13 ± 0.06[c]	0.13 ± 0.06[a]	3.29 ± 0.06[c]	1.17 ± 0.00[c]	6.17 ± 0.14[b]	50.35 ± 0.28[a]
D.AL/Z 6	7.83 ± 7.54[a]	1.71 ± 0.06[b]	6.13 ± 7.48[a]	2.38 ± 0.06[b]	0.67 ± 0.00[b]	4.80 ± 0.75[ab]	50.00 ± 0.07[a]
D.AL/Z 7	9.63 ± 6.54[a]	1.96 ± 0.29[bc]	7.67 ± 6.84[a]	3.21 ± 0.18[c]	1.25 ± 0.12[c]	3.97 ± 3.82[ab]	50.53 ± 0.04[a]
D.AL/Z 8	9.63 ± 6.54[a]	1.96 ± 0.29[bc]	7.67 ± 6.84[a]	3.21 ± 0.18[c]	1.25 ± 0.12[c]	3.97 ± 3.82[ab]	50.53 ± 0.04[a]
TGX 1740-2F	1.65 ± 0.08[a]	1.25 ± 0.07[a]	0.40 ± 0.04[a]	1.75 ± 0.12[a]	0.50 ± 0.07[a]	1.42 ± 0.26[a]	50.26 ± 0.19[a]
TGX 1940 6F	2.54 ± 1.32[a]	1.21 ± 0.08[a]	1.33 ± 1.40[a]	1.73 ± 0.12[a]	0.52 ± 0.08[ab]	2.1 ± 1.20[ab]	48.89 ± 1.55[a]
Min	1.65	1.21	0.13	1.73	0.50	1.42	48.89
Max	9.63	2.13	7.67	3.29	1.25	6.17	50.53
Mean	5.59	1.70	3.89	2.59	0.89	3.74	50.09
CV (%)	68.67	22.89	93.82	28.59	41.14	46.67	1.24

Notes: Means with different letters along columns are significantly different at $p < 0.05$.
CV = Coefficient of variation RVU = Rapid Visco Unit.

3.2. Correlation analysis of parameters of pipeline and improved soybean varieties

Tables 4 and 5 show the correlation results for proximate and functional properties and correlation between proximate components and pasting properties for the investigated soybean varieties respectively. There was significant positive ($p > 0.01$) correlation between protein and fat contents ($r = 0.768$), crude fiber and moisture contents ($r = 0.809$); and crude fiber and ash contents ($r = 0.670$). The strong and positive correlation observed between protein and fat indicates that it is easier to have varieties with high protein and fat contents for product development and Breeders could easily breed for high content of these parameters. Similarly, the explanation holds for crude fiber and ash contents that showed positive correlation. However, significant negative ($p > 0.01$) correlation was observed between fat and ash contents ($r = -0.910$) and significant ($p > 0.05$) but weak correlation between protein and ash contents ($r = -0.597$). This indicates that we could not breed or have varieties with high protein and ash contents. WAC showed weak correlation with all proximate components (moisture, ash, protein and crude fiber) but solubility had significant ($p > 0.01$) positive correlation ($r = 0.655$) with protein and this indicates solubility of the flour increases the protein content increases. Solubility is the amount of flour in a sample that dissolves into solution. This is an indication of amount of protein in a sample that goes into solution and it is very important indicator. Proteins recommended as food additives can be partly or completely soluble or completely insoluble

Table 4. Correlation coefficient (*r*) between proximate and functional properties of pipeline and improved soybean varieties

	Moisture	Ash	Fat	Protein	Crude fiber	WAC	Solubility
Moisture	1						
Ash	0.913*	1					
Fat	−0.969*	−0.910*	1				
Protein	−0.802*	−0.597*	0.768*	1			
Crude fiber	0.809*	0.670*	−0.770*	−0.680*	1		
WAC	0.323	0.106	−0.207	−0.198	0.327	1	
Solubility	−0.524**	−0.419	0.405	0.655*	−0.689*	−0.293	1

Note: WAC = Water Absorption Capacity.

*Correlation is significant at the 0.01 level.

**Correlation is significant at the 0.05 level.

Table 5. Correlation coefficient (*r*) between proximate and pasting properties of pipeline and improved soybean varieties

	Moisture	Ash	Fat	Protein	Crude fiber	Peak1	Breakdown	Final viscosity
Peak1	−0.521**	−0.582**	0.520**	0.241	−0.415	1		
Breakdown	−0.468	−0.534**	0.463	0.195	0-.378	0.997*	1	
Final viscosity	−0.747*	−0.720*	0.784*	0.473	−0.507**	0.451	0.377	1

*Correlation is significant at the 0.01 level.

**Correlation is significant at the 0.05 level.

in water. However, there was significant ($p > 0.01$) negative correlation between solubility and crude fibre as expected because crude fiber reduces solubility of the flour because fiber comprises true cellulose and insoluble lignin that are highly insoluble in water. Peak 1(Pasting viscosity) showed a significant ($p > 0.05$) negative correlation with ash ($r = -0.582$) and crude fiber ($r = -0.415$) but significant($p > 0.05$) positive correlation with fat ($r = 0.520$) and poor correlation with protein ($r = 0.241$). However, Final viscosity had significant ($p > 0.01$) positive correlation with fat ($r = 0.784$) and protein ($r = 0.473$) and significant ($p > 0.01$) negative correlation with ash ($r = -0.720$) and crude fiber ($r = -0.507$).

3.3. Nutritional properties of developed soy-based products

The nutritional properties of products fortified with Soybean flour are presented in Tables 6 and 7. The results show that Soy bread had significantly ($p < 0.05$) highest ash (3.22 ± 0. 04%),crude fiber (2.93 ± 0. 28%), protein (18.50 ± 0. 20%) and carbohydrate (68.76 ± 0. 64%) contents but had the lowest fat (6.58 ± 0. 20%) content. While Soy biscuits had the significantly ($p < 0.05$) lowest protein (12.86 ± 0.09%) content, its ash (2.90 ± 0.04%)and carbohydrate (62.61 ± 0.06%) contents were among the highest. Soycake had the highest fat (28.69 ± 0.32%) content, Soy pancake had a low fat (16.61 ± 0.09%) content compared to other products. The results also showed that the ash (0.75 ± 0.00%), fiber (0.02 ± 0. 01%) and fat (0.35 ± 0. 01%) contents of Soy yoghurt are low significantly ($p < 0.05$) when compared with Soy tofu and Salad cream. Soy tofu had a significant ($p < 0.05$) higher level of protein (30.7 ± 0.02%) content when compared with the Soy salad cream but the reverse is the case for the fat (12.69 ± 0.16%) contentas against fat content of 17.51 ± 0.02% for soysalad cream.

Table 6. Proximate properties of soy-fortified products in g per 100 g dry weight basis

Sample ID	MC	Ash	CF	Protein	Fat	CHO
Soy biscuits	6.45 ± 0.07^{a}	2.90 ± 0.04^{cd}	1.21 ± 0.13^{a}	12.86 ± 0.09^{a}	20.42 ± 0.02^{c}	62.61 ± 0.06^{c}
Soy muffins	21.22 ± 0.22^{d}	2.55 ± 0.08^{bc}	1.08 ± 0.02^{a}	14.40 ± 0.16^{b}	23.36 ± 0.36^{d}	58.6 ± 0.59^{b}
Soy chin chin	9.04 ± 0.08^{b}	1.92 ± 0.18^{a}	1.29 ± 0.2^{a}	14.84 ± 0.33^{b}	22.63 ± 0.39^{d}	59.32 ± 0.32^{b}
Soy pancakes	43.91 ± 0.07^{f}	2.19 ± 0.01^{ab}	2.48 ± 0.45^{b}	14.76 ± 0.04^{b}	16.61 ± 0.09^{b}	63.95 ± 0.39^{c}
Soy cakes	18.21 ± 0.1^{c}	2.32 ± 0.32^{ab}	1.17 ± 0.07^{a}	14.12 ± 0.14^{b}	28.69 ± 0.32^{e}	53.61 ± 0.07^{a}
Soy bread	35.99 ± 0.18^{e}	3.22 ± 0.04^{d}	2.93 ± 0.28^{b}	18.50 ± 0.20^{c}	6.58 ± 0.20^{a}	68.76 ± 0.64^{d}
Min	6.45	1.92	1.08	12.86	6.58	53.61
Max	43.91	3.22	2.93	18.50	28.69	68.76
Mean	22.47	2.52	1.69	14.93	19.72	61.14
CV (%)	60.23	17.31	43.22	11.56	34.95	7.75

Notes: Means with different letters along columns are significantly different at $p < 0.05$.
MC = Moisture content; CF = Crude Fiber; CHO = Carbohydrate.

Table 7. Proximate properties of soy-based products in g per 100 g dry weight basis

Sample ID	MC	Ash	CF	Protein	Fat	CHO
Soy youghut	87.31 ± 0.01^{c}	0.75 ± 0.00^{c}	0.02 ± 0.01^{a}	2.22 ± 0.03^{a}	0.35 ± 0.01^{a}	9.35 ± 0.04^{c}
Soy tofu	50.91 ± 0.42^{a}	1.46 ± 0.01^{b}	0.06 ± 0.0^{a}	30.7 ± 0.02^{c}	12.69 ± 0.16^{b}	4.18 ± 0.58^{a}
Soy salad cream	52.47 ± 0.17^{b}	1.05 ± 0.0^{a}	0.22 ± 0.01^{b}	16.12 ± 0.1^{b}	17.51 ± 0.02^{c}	12.64 ± 0.27^{b}
Min.	2.04	2.21	0.13	17.47	2.75	6.47
Max.	4.81	5.89	0.46	62.53	36.84	68.88
Mean	3.42	3.69	0.26	37.97	21.81	32.84
CV (%)	33.01	42.92	54.59	49.04	65.12	80.32

Notes: Means with different letters along columns are significantly different at $p < 0.05$.
MC = Moisture content; CF = Crude Fiber; CHO = Carbohydrate.

Since lower moisture can indicate higher shelf life of Soybean seed (Mbofung, 2012), the low moisture contents of Zambian varieties may indicate better storage ability and thus slower perishability. There was no wide difference in the range of ash contents of the varieties. In comparison to food composition databases (Marealle, 1974; WAFCT, 2012; USDA 2016), the new varieties contain significant higher amount of ash. The lipid content of Soybean is an essential property in the production of Soy oil which has several household and industrial applications. The carbohydrate in Soybean are largely non-bio available, Non Starch Polysaccharides (NSP) which human do not digest and the simple sugars may also need further processing to increase digestibility (Karr-Lilienthal, Kadzere, Grieshop, & Fahley, 2005). The low amylose content in the varieties may account for poor textural differences when used in different products (Chinma, Abu, James, & Iheanacho, 2012) because amylose content is one of the important factors affecting starch pasting and retro gradation behaviors. The protein content of the varieties investigated are well comparable to the values reported in the literature (Cheftel, Cuq, & Lorient, 1985). The protein content of Soybean is very valuable considering its amino acid composition, even though limiting in few amino acids, it provides substantial (high biological value) protein content compared to other legumes (Bressani, 1981; Snyder & Kwon, 1987; Watanabe, Ebine, & Ohda, 1971). The overall protein content of soybean does not differ considerably from one variety to another as observed also by Berk (1992). The high crude fiber content recorded indicates that these Soybean varieties could be a good source of dietary fiber composition, the values compared favorably with the results of Akubor and Onimawo (2003) and Vasconcelos et al. (2006). The higher values could be attributed to the sample preparation method, in which the samples were not dehulled before analysis. This substantial fiber content is of particular interest as it can provide increased bowel movements which has been suggested to reduce diseases of lower gastrointestinal tract (Lokuruka, 2010). Conversely, it can negatively influence the bioavailability of some micro nutrients during metabolism (Passmore & Eastwood,1986). These high protein and fat values of D.AL/Z 6 and D.AL/Z 9 indicate a high nutrient density and hints that these two varieties could contribute significantly to nutrient intake. Generally, the nutrient compositional values obtained in this study are similar to literature values for Soybean seeds (Anuonye, Onuh, Egwim, & Adeyemo, 2010; Cheftel et al., 1985; Marealle, 1974; USDA, 2016; WAFCT, 2012). Since the samples were subjected to similar sample preparations, the variations in composition observed might be attributed to different locations of planting and varietal differences which could affect expression of these varieties in various environmental conditions as suggested from literature (Kennedy & Burlingame, 2003; Kuo, Eskins, & Cooper, 1997; Lokuruka, 2010; Vasconcelos et al., 2006). However, the observed small percentage co-efficient of variation of the proximate parameters show that the properties of the investigated varieties do not vary by a large range. Functional properties are the properties that influence the behavior of proteins in food systems during processing, storage, cooking and consumption, manufacturing, storage and preparation (Jideani, 2011; Kinsella, 1976). When compared with similar literature values (Akubor & Onimawo, 2003), the Water Absorption Capacity (WAC) recorded is high and these may be indicative of the undehulled nature of the seeds used and high crude fiber contents. This characteristic may be of value to improve yield and consistency of dough in product making (Osundahunsi, Fagbemi, Kesselman, & Shimoni, 2003). High water absorption increases products yield and affects final products attributes. Water Binding Capacity (WBC) reveals the intermolecular associations between starch polymers (Rincon, Padilla, Araujo, & Tillet, 1999). The wide range of WBC in these cultivars may be attributed to a varietal difference. These high values suggest that the seeds may have to be processed further to be suitable in producing complementary foods for infants and young children (Malomo et al., 2012). The differences in the varieties could be further seen in the bulk density, solubility and dispersibility values and these parameters have direct relation to the flour quality and food structure that could be produced using these varieties .The pasting behavior of flour is very important for its characterization and applications in product development. Even though Liu and Chang(2007) found an interaction between protein content and variety on viscosity, it is uncertain if the variability obtained in this study is influenced by the genetic variation of the varieties. In comparison with another common legume- cowpea- the pasting properties of soybean seeds are poor and this may be attributable to a lower content oligosaccharide composition which is more in cowpea (Eldridge, Lynn, Black, & Wolf, 1979; Parsons, Zhang, & Araba, 2000). The low pasting viscosity values found for most varieties indicate that it could not be used as part of ingredients for food formulations of high gel strength products. The peak viscosity occurs at the equilibrium point between the swelling and rupturing of starch granules, swelling causing an increase in viscosity and rupture and alignment causing its decrease. According to Afoakwa and Sefa-Dedeh (2002), pasting temperature, which is also related to paste stability, gives an indication of the strength of associative forces within the granules. However, the low pasting time indicate low cooking time, while low pasting temperature is an indication of the minimum temperature required to cook each of the varieties, which can have implications for the stability of other components in the products and also indicate energy costs. The results show that despite the genetic and agronomic differences the varieties could possess, they may perform similarly at the level of product development. Soy bread and Soy biscuits had a higher ash content compared to other products and thus may contribute more minerals after consumption. The low coefficient of variation of protein and carbohydrate contents in the products indicate that the various products retain similar amounts of Soy protein and carbohydrate contents, while other nutrient values may differ with changing recipes. The large negative difference in fat content of bread in comparison to other products may be as a result of the recipe. Soy yoghurt has very low ash and fat contents compared to Soy tofu and Soy salad cream, this low values may imply that fortification is needed to improve the nutrient content of Soy yoghurt. With the exception of the fat contents the results obtained are similar to those of Osundahunsi, Amosu, and Ifesan (2007), Farinde, Adesetan, Obatolu, and Oladapo (2009). The moisture and protein contents of the Soybiscuit were lower t but the ash and fat values were similar to the values reported by Okoye, Nkwocha, and Ogbonnaya (2008) and Banureka and Mahendran (2009). These variations could be as a result of different methods of processing and initial nutrient contents.

4. Conclusion

This study has evaluated the proximate, functional and pasting properties of pipeline and improved Soybean varieties and the developed products from Zambia. The proximate compositions of the newly developed varieties showed that they can provide nutritional efficacy. Considering the functional and pasting properties results, there is an indication that they can be adapted locally for product development. The various products presented are either newly developed or commonly consumed and thus could be adapted as need be for households. Even though this study has presented some food compositional information on different varieties of Soybean in Zambia, it is important to gather more food compositional data on the varieties especially the specific compositions such as the amino acid compositions, the dietary fiber, fatty acid composition and the anti-nutritionals. This will improve the prediction of recommendations of varieties as the need may arise.

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