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Protein quality and functional properties of *masa* produced from maize, *acha* and soybean

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Abstract

In the developing countries, the greatest problems affecting millions of people is food insecurity and lack of adequate diet. The study investigated the effect of *acha* and soybean substitution on the quality of maize *masa*. Amino acid profile, functional properties, α-amylase activity and sugar contents were determined using standard methods. Protein efficiency ratio, essential amino acid index and biological value were calculated from the amino acid profile. The addition of *acha* and soybean to *masa* significantly increased the essential amino acids, predicted protein efficiency ratio, essential amino acid index, and biological value of *masa.* Water absorption, oil absorption and swelling capacity of *masa* were within the range of 78.00-84.30%, 79.00-86.50% and 71.70-102.00% respectively. It is therefore concluded that the substitution of maize with *acha* and soybean increased the nutritional quality of *masa*.

1. Introduction

Masa is a cereal-based spontaneously fermented cake popularly consumed in Nigeria and Ghana as snack or adjunct to breakfast porridges (Owusu-Kwarteng and Akabanda, 2014). It is mainly produced from common cereal such as maize, rice or millet. It is eaten with granulated sugar or with honey because of its sour tastes (Sanni and Adesulu, 2013; Samuel *et al*., 2015).

Maize (*Zea mays*) is an important cereal grain in the world and it has a diverse form of utilization including human food uses, animal feeds formulation and raw materials for industries (Sanni and Adesulu, 2013). Maize can be processed in so many ways depending on the desired product. It can be eaten boiled or roasted, fermented into traditional food products such as *ogi, banku, kunnu* and *masa,* processed into meal or flour and or used as an adjunct in breweries (Oladejo and Adetunji, 2012).

Acha (*Digitaria exilis*), an underutilized cereal of West African origin is abundant in the North-Central part of Nigeria (Philip and Itodo, 2012) and is considered to be the oldest West African cereal with cultivation dating back to 5000 BC (Haq and Ogbe, 1995). *Acha* is perhaps the world's fastest maturing cereal, producing grains six to eight weeks after planting. It has the potential of providing enough food for the increasing population of West Africa and the world at large (Echendu *et al.,* 2009). It does not contain any glutenin or gliadine proteins which are the constituents of gluten, making this cereal suitable for people with gluten intolerance (Jideani, 1999; Ayo *et al*., 2014).

The dependence on cereal as a staple food in tropical African countries has necessitated the need for improving the quality and acceptability of cereal-based foods. Legumes are sources of low-cost dietary vegetable proteins and minerals when compared with animal products such as meat, fish and egg. Enrichment with locally available and cheap source of protein such as soybean will increase the amino acid balance (Adesokan *et al*., 2011). Cereal is generally deficient in tryptophan and lysine which is abundant in legume. Thus, the purpose of this study was to assess the effect of *acha* substitution and soybean fortification on the amino acid, α-amylase, sugars and functional properties of *masa.*

2. Materials and methods

Acha was obtained from Zaria in Nigeria and identified at the herbarium of the Department of Botany, Obafemi Awolowo University, Ile - Ife. Quality Protein Maize (Ile-1-OB) and soybeans (TGX 1740 2E) were obtained from Institute of Agricultural Research and Training, Ibadan, Nigeria and chemicals and reagents used were of analytical grade (BDH, England).

2.1 Preparation of masa

Masa was produced using the modified method of

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Owusu-Kwarteng and Akabanda (2014) (Figure 1). Maize and *acha* were cleaned, weighed, washed, steeped in water for 12 hrs at ambient temperature (27±2°C), washed and drained. Soybean was cleaned and steeped in water for 2 hrs at room temperature (27±2°C), blanched for 20 mins in boiling water and dehulled by hand and hull was separated from the cotyledon and drained. Maize, *acha*, and soybean seeds were mixed at ratios: 100:0:0, 0:100:0, 70:20:10, 60:30:10, 60:20:20, 50:40:10, 50:30:20, 40:40:20 to make 100 g each and then milled. The batter obtained was divided into three portions. One-third of each ground sample was mixed with an equal amount of water and then pregelatinized. The pregelatinized portions were mixed with the uncooked two third portions and resulting batter from the mixtures was spontaneously fermented for 24 hrs at ambient temperature (27±2°C) and dried in Gallenkamp hot air oven (Model OV-440) at 60°C, cooled in a desiccator and ground into flour.

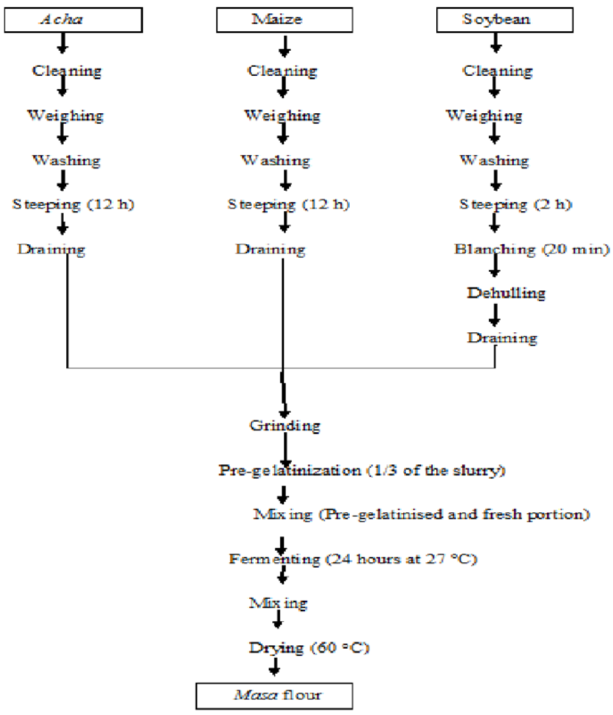

Figure 1. Production of *masa*

2.2 Analysis of the profile of amino acids

Amino acid composition was determined using Amino Acid Analyzer. Samples were freeze-dried and then hydrolyzed at 110°C for 24 hrs with 6N HCl. After hydrolysis, the samples were stored frozen in sodium citrate buffer at pH 2.2. 50 µl of the hydrolysate was injected into amino acid analyzer for analysis. Tryptophan was determined separately by hydrolysis of the sample with sodium hydroxide. Cysteine and methionine were determined after performic acid oxidation prior to hydrolysis in 6N HCl, and was measured as cysteic acid and methionine sulphone, respectively (Blackburn, 1978; Gbadamosi *et al.*, 2012).

2.3 Determination of nutritional quality

The Essential Amino Acid Index (EAAI), Biological value (BV) and the Predicted Protein Efficiency Ratio (PER) were calculated from the amino acid profile. The Essential Amino Acid Index (EAAI) was determined using the equation of Labuda *et al.* (1982) as described by Ijarotimi and Keshinro (2013).

$$EAAI = \sqrt[9]{\frac{(lys \times Tryp \times Iso \times Val \times Thre \times Isoleu \times leu \times meth \times hist)a}{(lys \times Tryp \times Iso \times Val \times Thre \times Isoleu \times leu \times meth \times hist)b}}$$

Where [lysine, tryptophan, isoleucine, valine, threonine, leucine, phenylalanine, histidine and methionine]a in test sample and [lysine, tryptophan, isoleucine, valine, threonine, leucine, phenylalanine, histidine and the sum of methionine and cystine]b content of the same amino acids in standard protein (%) (egg or casein) respectively.

Biological value was calculated according to Oser (1959):

BV = 1.09 x Essential amino acid index (EAAI) - 11.7

The Predicted Protein Efficiency Ratio (PER) was estimated according to the regression equations developed by Alsmeyer *et al.* (1974) as given below:

P-PER = -0.468 + 0.454(LEU) - 0.105(TYR)

2.4 Determination of functional properties

Water absorption capacity, oil absorption capacity and swelling capacity were estimated from the dried *masa* samples.

2.4.1 Water absorption capacity

Water absorption capacity was determined using the method of Adebowale *et al.* (2005). Ten milliliters of distilled water were added to 1.0 g of each sample in beakers. The suspension was stirred using a magnetic stirrer for 5 mins. The suspension obtained was thereafter centrifuged (Bosch Model No TDL-5, Germany) at 3555 rpm for 30 mins and the supernatant was measured in a 10 mL graduated cylinder. The density of water was taken as 1.0 g/cm^3. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant.

2.4.2 Oil absorption capacity

Oil absorption capacity was determined using the method of Adebowale *et al.* (2005). Ten milliliters of distilled water were added to 1.0 g of each sample in beakers. The suspension was stirred in Lab line magnetic

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stirrer for 5 mins. The suspension obtained was thereafter centrifuged (Bosch Model No TDL-5, Germany) at 3555 rpm for 30 mins and the supernatant was measured in a 10 mL graduated cylinder. Oil absorbed was calculated as the difference between the initial volume of oil added to the sample and the volume of the supernatant.

2.4.3 Swelling capacity

Swelling capacity was determined by the method described by Adepeju *et al*. (2014). Sample (1 g) was weighed into 50 mL centrifuge tube. Distilled water (30 mL) was added and mixed gently. The slurry was heated in water bath (Gallenkomp, HH-S6, England) at 95°C for 30 mins. During heating, the slurry was stirred gently to prevent clumping of the sample. The tube containing the paste was centrifuged (Bosch Model No TDL-5, Germany) at 3000 x *g* for 10 mins and the supernatant was decanted immediately after centrifugation. The tubes were dried at 50°C for 30 mins, cooled and then weighed (W_2). Centrifuge tubes containing sample alone were weighed prior to adding distilled water (W_1).

2.5 Statistical analysis

Data obtained were subjected to descriptive and inferential statistics using SPSS (version, SPSS, Inc., USA). Means of samples were separated using Duncan Multiple range Test (SAS Institute 1985).

3. Results and discussion

3.1 Amino acid profile of fermented masa samples

The essential amino acids of the *masa* flour samples are shown in Table 1. Valine content of *masa* flour samples ranged between 3.49 – 4.86 g/100 g protein. It was higher in *masa* flour produced from 100% *acha* than 100% maize. Valine content of *masa* flour were higher than FAO standard (3.50 g/100 g protein) but slightly lower in samples produced from 50% maize: 30% *acha*: 20% soybean and 40% maize: 40% *acha*: 20% soybean (3-49 g/100 g of protein) but generally lower than egg protein (4.30 g/100 g protein). Histidine was within the range of 1.74 to 2.94 g/100 g of protein. It was significantly higher ($p<0.05$) in *masa* flour produced from 100 % *acha* than 100 % maize and increased with increase with soybean fortification. Histidine was higher in samples fortified with soybean than FAO standard (1.9 g/100 g protein) and egg protein (2.40 g/100 g protein) but lower in flour samples fortified with 10% soybean (1.93 – 2.37 g/100 g protein) than egg protein. Phenylalanine was higher in all *masa* flour samples than FAO standard (2.8 g/100 g protein) but lower than egg protein as expected in flour produced from 100% *acha* (5.48 g/100 g protein). Methionine was within the range of 0.84 to 1.58 g/100 g of protein. It was significantly higher ($p<0.05$) in 100% maize than 100% *acha*. The level of methionine + cysteine in all *masa* flour (2.03 – 2.95 g/100 g protein) were higher than the FAO standard (2.2 g/100 g protein) for preschool children except in *masa* flour produced from 100% *acha* (2.03 g/100 g protein). Lysine was within the range of 2.90 to 5.08 g/100 g of protein. It was highest in *masa* flour produced from 100% *acha* and higher in soybean fortified samples than 100% maize. Leucine content ranged between 6.34 to 8.37 g/100 g of protein and was the most abundant essential amino acid in the *masa* flour. It was significantly higher ($p<0.05$) in 100% *acha* than 100% maize and also increased with an increase in soybean fortification. Leucine content of *masa* flour samples was higher than egg protein (5.30 g/100 g protein) and FAO standard (6.60 g/100 g protein). *Masa* flour produced from 100% *acha* had the highest threonine content, followed by 100% maize. Threonine was higher in *masa* flour sample produced from 100% *acha* (4.50 g/100 g protein) than in FAO standard (3.40 g/100 g protein) but lower in 100% maize (2.89 g/100 g protein). The value of valine (5.8) and leucine (9.8) reported by Ballogou *et al.* (2013) for raw *acha* was higher than the value obtained in this study. This could be due to losses during fermentation because bacteria utilize amino acids for growth. Soybean is high in lysine, but low in sulphur-containing amino acids, with methionine being the most limiting amino acid, followed by threonine (Chen *et al.,* 2013). Essential amino acids were higher in *masa* samples produced from 100% *acha* than 100% maize. Tryptophan was higher samples fortified with soybean (1.14 – 1.45 g/100 g protein) except in sample produced from 60% maize, 30% *acha* and 10% soybean (1.06 g/100 g protein) than in FAO standard (1.1 g/100 g protein).

The non-essential amino acids of fermented *masa* are shown in Table 2. The glycine, serine, glutamate, cysteine and proline content of *masa* were within the range of 4.34 to 4.80, 7.06 and 9.22, 20.06 to 22.53, 1.19 to 1.70 and 5.72 to 6.49 g/100 g of protein respectively. These amino acids were significantly higher ($p<0.05$) in *masa* flour produce from 100% maize than 100% *acha* and also increase with fortification with soybean.

Alanine, aspartate and tyrosine were within the range of 4.15 to 6.24, 9.72 to 11.78 and 2.17 to 3.67 g/100 g of protein respectively. These amino acids were significantly higher ($p<0.05$) in *masa* flour produce from 100% *acha* than 100% maize. Non-essential amino acids were higher in *masa* flour produced from 100% maize than 100% *acha*. Glutamate was the most abundant non-essential amino acid.

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Table 1. Essential amino acid profile of *masa* (g/100 g of Protein)

Amino acids	*Masa* Samples								FAO/WHO (1985) (2-5years)	Egg Protein
	100% M	100% *A*	70% M:20% *A*:10%S	60% M:30% *A*:10%S	60% M20% *A*:20%S	50% M:40% *A*:10%S	50% M:30% *A*:20%S	40% M:40% *A*:20%S		
Valine	4.00±0.06^{d}	4.86±0.05^{a}	4.03±0.01^{d}	4.43±0.02^{c}	4.58±0.03^{b}	3.92±0.04^{e}	3.49±0.06^{f}	3.49±0.03^{f}	3.5	4.3
Threonine	2.89±0.03^{b}	4.50±0.04^{a}	2.21±0.03^{e}	2.59±0.06^{c}	2.11±0.07^{f}	1.97±0.03^{h}	2.08±0.04^{g}	2.32±0.07^{d}	3.4	2.9
Isoleucine	2.76±0.07^{e}	3.87±0.05^{a}	2.53±0.02^{g}	3.06±0.05^{b}	2.19±0.03^{h}	2.72±0.09^{f}	2.86±0.02^{d}	3.05±0.03^{c}	2.8	4.0
Leucine	6.34±0.08^{h}	7.18±0.06^{d}	6.55±0.06^{g}	6.86±0.03^{e}	8.37±0.07^{a}	6.77±0.06^{f}	7.67±0.03^{c}	8.30±0.06^{b}	6.6	5.3
Lysine	2.90±0.03^{g}	5.08±0.03^{a}	3.11±0.05^{f}	3.12±0.04^{f}	3.54±0.05^{d}	3.86±0.03^{b}	3.43±0.05^{e}	3.60±0.04^{c}	5.8	3.7
Methionine	1.41±0.09^{b}	0.84±0.04^{h}	1.13±0.02^{g}	1.29±0.08^{d}	1.58±0.04^{a}	1.36±0.02^{c}	1.27±0.06^{e}	1.23±0.01^{f}	2.2	3.2
Phenylalanine	4.48±0.04^{c}	5.48±0.05^{a}	4.52±0.01^{b}	4.34±0.09^{d}	2.73±0.03^{h}	2.86±0.08^{g}	3.08±0.05^{f}	3.39±0.05^{e}	2.8	5.1
Histidine	1.74±0.10^{h}	1.82±0.03^{g}	1.93±0.04^{f}	2.37±0.02^{d}	2.55±0.06^{b}	2.31±0.04^{e}	2.46±0.04^{c}	2.59±0.07^{a}	1.9	2.4
Tryptophan	1.02±0.02^{e}	0.78±0.06^{f}	1.14±0.03^{d}	1.06±0.04^{e}	1.38±0.01^{c}	1.39±0.07^{c}	1.45±0.02^{a}	1.40±0.10^{b}	1.1	1.8
Methionine + cysteine	2.95	2.03	2.83	2.93	2.95	2.85	2.90	2.59	2.5	-
Phenylalanine + Tyrosine	6.93	9.15	6.86	6.51	5.19	5.68	6.06	5.92	6.3	-

M: Maize; A: Acha; S: Soybean. Values are means of three replicates ± standard error. Means followed by different superscript in the same row are significantly different at $p<0.05$

Table 2. Non essential amino acid profile of *masa* (g/100g of Protein)

Amino acids	*Masa* Samples							
	100% M	100% *A*	70%M:20% *A*:10%S	60%M:30% *A*:10%S	60%M20% *A*:20%S	50%M:40% *A*:10%S	50%M:30% *A*:20%S	40%M:40% *A*:20%S
Glycine	4.52±0.06^{e}	4.34±0.02^{h}	4.79±0.06^{b}	4.56±0.06^{d}	4.80±0.03^{a}	4.63±0.04^{c}	4.44±0.06^{g}	4.50±0.04^{f}
Alanine	4.15±0.03^{h}	6.24±0.07^{a}	4.31±0.01^{g}	4.81±0.06^{e}	5.28±0.02^{b}	5.23±0.01^{c}	4.58±0.04^{f}	4.93±0.06^{d}
Serine	8.92±0.07^{e}	7.06±0.06^{h}	8.64±0.03^{f}	8.43±0.04^{g}	9.10±0.06^{c}	9.13±0.04^{b}	9.03±0.03^{d}	9.22±0.04^{a}
Proline	6.49±0.04^{b}	4.30±0.03^{g}	5.72±0.07^{f}	5.72±0.06^{f}	6.43±0.10^{c}	6.33±0.07^{d}	6.83±0.06^{a}	6.30±0.09^{e}
Aspartate	10.46±0.09^{c}	11.78±0.06^{a}	9.72±0.01^{h}	10.27±0.03^{d}	10.01±0.04^{f}	10.04±0.06^{e}	9.76±0.04^{g}	10.59±0.06^{b}
Glutamate	20.99±0.01^{c}	20.06±0.07^{f}	20.08±0.04^{f}	21.00±0.01^{c}	22.53±0.06^{a}	20.26±0.06^{e}	21.93±0.07^{b}	20.82±0.06^{d}
Tyrosine	2.45±0.02^{f}	3.67±0.07^{a}	2.34±0.06^{g}	2.17±0.07^{h}	2.46±0.05^{e}	2.82±0.07^{c}	2.98±0.02^{b}	2.53±0.05^{d}
Cysteine	1.54±0.07^{d}	1.19±0.05^{h}	1.70±0.06^{a}	1.64±0.06^{b}	1.37±0.01^{f}	1.49±0.01^{e}	1.63±0.04^{c}	1.36±0.07^{g}

M: Maize; A: Acha; S: Soybean. Values are means of three replicates ± standard error. Means followed by different superscript in the same row are significantly different at $p<0.05$

Table 3. Nutritional properties of *masa* flour

Nutritional Value	*Masa* Samples							
	100% M	100% *A*	70%M:20% *A*:10%S	60%M:30% *A*:10%S	60%M20% *A*:20%S	50%M:40% *A*:10%S	50%M:30% *A*:20%S	40%M:40% *A*:20%S
TAA	87.06	93.05	84.45	87.72	91.01	87.09	88.97	89.62
TEAA	27.54	34.41	27.15	29.12	29.03	27.16	27.79	29.37
TNEAA	59.52	58.64	57.30	58.60	61.97	59.93	61.18	60.25
TNEAA/TAA%	46.27	58.68	47.38	49.69	46.84	45.32	45.42	48.75
TEAA/TAA%	31.63	36.98	32.15	33.20	31.90	31.19	31.24	32.77
TSAA(Met+Cys)	2.95	2.03	2.83	2.93	2.95	2.85	2.90	2.59
ArEAA(Phe+Tyr)	5.50	6.26	5.66	5.40	4.11	4.25	4.53	4.79
TEAA/TNEAA	0.46	0.59	0.47	0.50	0.49	0.45	0.45	0.49
PER (g/100g)	2.30	2.71	2.39	2.53	3.19	2.46	2.86	3.15
EAAI (%)	64.00	142.0	72.30	111.00	98.20	83.30	87.80	123.40
BV (%)	58.06	143.0	67.11	109.29	95.39	79.10	84.00	122.81

Total essential amino acids (TEAA), Total amino acids (TAA), Total non-essential amino acids (TNEAA), Total sulphur amino acids (TSAA), Aromatic essential amino acids (TArEAA), Protein efficiency ratio (PER), Essential amino acid index (EAAI), Biological value (BV). M: Maize*; A: Acha*; S: Soybean

Fortification with soybean increased the amino acid profile especially tryptophan, lysine, leucine, histidine, serine, proline and glutamate. This was in agreement with previous work by Ng'ong'ola-Manani *et al*. (2014) during fermentation of soybean and blends of maize-soybean. Amino acid aids the development of aroma and taste in food because of involvement in Maillard reactions and Strecker degradation (Dajanta *et al*., 2011; Ng'ong'ola-Manani *et al*., 2014).

3.2 Nutritional quality of masa samples

Nutritional quality of *masa* flour samples is presented in Table 3. Total essential amino acid was higher in 100% *acha* (33.9%) than 100% maize (31.56%) while the total non-essential amino acids were higher in 100% maize than 100% *acha*. Methionine plus cystine value of *masa* flour samples (2.59 – 2.95 mg/100 g protein) were generally higher than that of FAO reference except in 100% *acha* (2.03 g/100 g protein) and the total aromatic amino acid was higher in 100% *acha* (6.26 g/100 protein) than 100% maize (5.50 g/100 g protein) but was generally lower than FAO reference standard (6.3 g/100 g protein) in all *masa* flour samples. The protein efficiency ratio was higher in *masa* flour produced from 100% *acha* (2.71%) than 100% maize (2.30%). The essential amino acid requirements according to FAO/WHO/UNU (1985) are (g/100 g cp) (with Histidine): pre-school (2-5 yrs) (33), school child (10-12 yrs) (24.1) adult (12.7); (without histidine): preschool (32.0), school child (22.2) and adult (11.1) (Adubiaro *et al.,* 2017). The total essential amino acid levels in *masa* flour are lower than the amount required by preschool children except in *masa* flour produced from 100% *acha* but meet the standards for school children and adult. The percentage of the total essential amino acid to total amino acid of all *masa* flour samples were above 26% considered to be adequate for ideal protein food for children and 11% for adults (FAO/ WHO/UNU, 1985; Adubiaro *et al.,* 2017).

Fortification with soybean also increased the protein efficiency ratio (PER) of *masa* flour samples and the increase was higher in samples fortified with 20% soybean than 10% soybean. *Masa* flour produced from 60% maize, 20% *acha* and 20% soybean had the highest protein efficiency ratio. The essential amino acid index of *masa* flour increased with increase in substitution with *acha* and fortification with soybean. Flour produced from 100% *acha* (142.90%), 60% maize, 30% *acha* and 10% soybean (111.00%), 60% maize, 20% *acha* and 20% soybean (98.20%), 50% maize, 40% *acha* and 10% soybean (83.30%), 50% maize, 30% *acha* and 20% soybean (87.80%), 40% maize, 40% *acha* and 20% soybean (123.40%) can be used as food because their essential amino acid index is greater than 80% and only *masa* flour sample produced from 100% maize had less than 70%. *Masa* flour produced from 100% *acha* (143.08%) had the highest biological value while 100% maize (58.06%) had a lower biological value. Addition of *acha* and fortification of *masa* flour with soybean increased its biological value.

Scientifically, it is well known that a protein-based food material is of good nutritional quality when its biological values (BV) is high (70 to 100%) and also when the essential amino acid index (EAAI) is above 90% and to be useful as food when the values are around 80% and to be inadequate for food material when its essential amino acid index is below 70% (Oser, 1959). The greater the essential amino acid index, the more balanced amino acid composition and the higher quality and efficiency of the protein (Fang *et al.,* 2018).

3.3 Water absorption capacity of fermented masa

Water absorption capacity represents the ability of the products to associate with water under conditions when water is limiting such as doughs and pastes. The water absorption capacity of the *masa* flour is presented in Figure. 2. It ranged between 78.00% and 84.30%. It was highest at 100% maize and lowest in 100% *acha*. There was no significant difference in water absorption capacity of *masa* produced from 100% maize and 60% maize:20% *acha*:20% soybean. It decreased with increase in *acha* substitution and increased with fortification with soybean.

Difference in hydrophilic constituents may be responsible for the difference in water absorption capacity. The polar amino-acids are the preferred sites of the interactions between water and proteins. Several authors attributed high water absorption capacity to lose structure of starch polymers while low value indicates compactness of the structure (Adebowale *et al*., 2005; Oladipo and Nwokocha, 2011; Compaoré *et al*., 2011; Abegunde *et al*., 2014). Addition of soybean increased water absorption capacity of complementary diet produced from maize and *acha* (Ikujenlola, 2014).

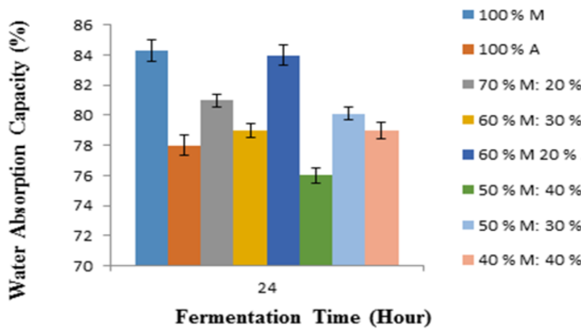

Figure 2. Water absorption capacity of *masa.* M: Maize*; A: Acha*; S: Soybean

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3.4 Oil absorption capacity of fermented masa

Oil absorption capacity of *masa* flour is shown in Figure 3. It was within the range of 79.00% and 86.50%. It was higher in *masa* flour produced from 100% *acha* than 100% maize. It was highest in the sample containing 100% *acha* followed by 50% maize:40% *acha*:10% soybean. It increased with increase in *acha* substitution. Oil absorption capacity has been attributed to entrapment of oil and the binding of fat to the hydrophobic amino acid. High oil absorption is a prerequisite for the formulation of foods such as sausages, cake batters, mayonnaise and salad dressings (Adepeju *et al.,* 2014).

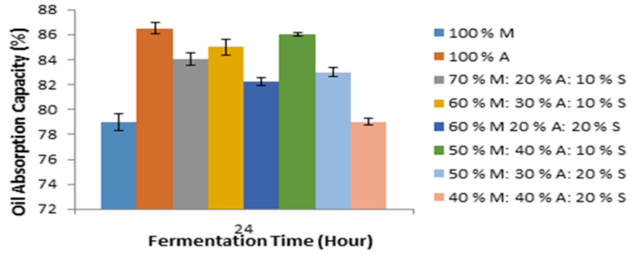

Figure 3. Oil absorption capacity of masa. M: Maize; A: *Acha*; S: Soybean

3.5 Swelling capacity of masa

This is the ability of flour to retain water within a given period. Swelling capacity of *masa* flour is shown in Figure 4. It was within the range of 71.70% and 102.00%. It was higher in *masa* produced from 100% maize than 100% *acha* and decreased with soybean fortification. Swelling power has been attributed to the associative binding of water within the starch granules and apparently, the strength and character of the micellar network is related to the amylose content of starch, low amylose content produces high swelling power (Akanbi *et al*., 2009; Gbadamosi and Oladeji, 2013). The presence of naturally occurring non-carbohydrates such as lipid is also an important factor. The formation of amylase lipid complexes can restrict swelling and solubilisation (Adegunwa *et al*., 2011).

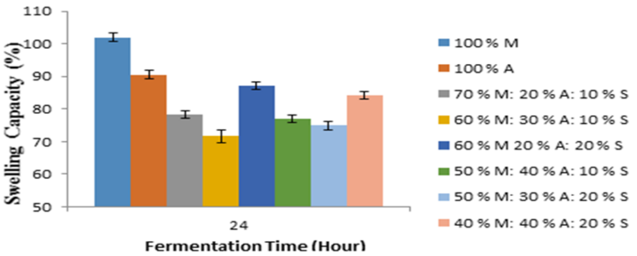

Figure 4. Swelling capacity of masa. M: Maize; A: *Acha*; S: Soybean

4. Conclusion

The addition of *acha* and soybean to *masa* resulted in the increase in essential amino acids, biological value, protein efficiency ratio. Thus, *masa* of good quality protein could be produced by the addition of *acha* and soybean. This will combat malnutrition and advance the utilization of *acha*.

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