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Effect of pH and temperature on selected functional properties of flour samples and protein isolate of cowpea (*Vigna unguiculata*) seeds

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ABSTRACT

Cowpea seeds were processed into flours by defatting and by protein isolation. Full fat cowpea flour was also obtained from cowpea seeds and this served as control. Functional properties of full fat, defatted and protein isolate cowpea flours were determined. Effects of temperature and pH on bulk density (BD), water absorption capacity (WAC), gelatinization temperature (GT), foaming capacity (FC), swelling index (SI) and emulsion capacity (EC) were studied. Functional properties show that bulk density (BD) ranged from 0.06 – 1.88g/ml, WAC (2.13 – 3.03ml/g), oil absorption capacity OAC (2.32 – 5.49ml/g), FC (3.01 – 33.23%), emulsion capacity EC (46.57 – 88.07%), SI (1.62 – 3.14) and gelatinization temperature, GT (0 – 81.97°C). There were significant differences ($p<0.05$) in the functional properties of full fat, defatted and protein isolate cowpea flours. Effect of temperature showed that lower temperature gave higher values of WAC, FC and SI and vice versa for higher temperature. Temperature at 40°C gave high values of WAC, FC and SI while temperature at 70°C gave low values. Effect of pH on WAC, FC and SI of full fat, defatted and protein isolate cowpea flours showed no consistency in the values obtained. Generally the study revealed that full fat, defatted and protein isolate cowpea flours gave good functional properties. However, processing of cowpea seed into flour by defatting and protein isolation displayed good functionalities and could have promising food application in Nigeria.

KEYWORDS

Functional properties;
Cowpea;
Flour;
Protein isolate;
pH;
Temperature.

INTRODUCTION

Legumes are the edible seeds of leguminous plants. Those used as food are divided into two groups namely; the pulse and oil seed[1]. The high protein content of varieties of legumes make them important sources of protein in the diet of population groups of many countries[16,17]. Grain legumes contributed the main sources of protein in the diet of the average African home. The most important ones are other pulses that could help meet dietary needs but are cultivated only in the localized areas and used less. A mature grain legume seeds has three

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major components – the seed coat (testa and hull), the cotyledon and the embryo axis[7]. Leguminous seeds are important sources of protein, energy and other nutrients in the diet of large population group around the world forming an excellent source of thiamine and contributing appreciable quantities of the other water soluble vitamins (riboflavin, niacin and pyridoxine and of the minerals (phosphorus, iron, calcium, and magnesium)[4].

Cowpea is among the dry leguminous seeds cultivated for food in the eastern part of Nigeria, where it is popularly known as *Akidi*, it is consumed as portage after prolonged into moi-moi or *Akara* while the young immature are used as vegetables, the main meal dishes can be prepared from the grain. Cowpea is of major importance to the likelihood of millions of relatively poor people in less developed countries of the tropics because it provides a cheap source of good nutrition. Due to the high protein content of cowpea seeds, it could be used to complement protein obtained from grains such as rice and starchy foods live cassava and plantain[9]. Also the high protein content of cowpea flour could be substituted or blended with wheat flour to produce bread, leavened dough that are of acceptable qualities. Cowpeas are a major source of dietary protein in developing countries. As animal protein is expensive in order to alleviate protein energy, malnutrition and product diversification of cowpea, greater attention should be paid to its exploitation. The objective of this study therefore was to find out the functional properties of flour produced from cowpea by defatting, protein isolation and dehulled full fat, determine the effects of pH and temperature on some of these functional properties so as to ascertain its potential in food formulation.

MATERIALS AND METHOD

Source of material

Cowpea seed in the project work were obtained from Nkwo Umuezeala, a local market in Isiala Mbano, Imo State, Nigeria. Laboratory and other facilities used in the practical were sourced from central laboratory service unit of National Root Crops Research Institute (NRCR), Umudike, Umuahia, Abia State.

Equipment

Equipment and instrument used in this study included the satorious digital weighing balance, cabolite electric oven, colab electric centrifuge, general laboratory glass wares, pH meter, thermometer, Authur Thomas laboratory mill and retort stand, stop watch, etc.

Chemical and reagents

The chemical and reagents used in the project were of analytical grade (Analar) and they include hydrochloric acid, and ethanol.

Sample preparation

Prior to isolation of protein, cowpea seeds were processed. The method described by Okezie and Bello[2] was employed. First, the bean seeds were sorted manually to remove extraneous materials like dirt, residue, shriveled and diseased seeds. The healthy wants were used.

Production of full fat of cowpea flour

In the production of full fat cowpea flour, dry seeds were soaked in water for 30minutes; and the seeds were manually dehulled to separate the seeds coats from the cotyledon, the dehulled seeds were derived in the oven at temperature of 30°C for 48hours before they were found with a laboratory mill, the sample was sieved through a 0.5mm sieve to obtain flour sample analysis.

Production of defatted cowpea flour

The full fat flour sample was soaked in the solvent at 1.5 (w/v) ratio and allowed to stand overnight at room temperature. The next day the mixture was filtered with filtration apparatus. The defatted flour was air dried for 8hours and pulverized in a mortar part of the defatted flour was set aside for analysis while the rest were used for the production of protein isolate.

Production of protein isolate

The protein isolation was done following the method described by Okezie and Bello[2]. 70g of flour with 1400ml of water was mixed to form a 1:20 (w/v) ratio of slurry. The solution at pH 6.37 was allowed to settle for 3hours. The spent residue was separated from the dissolved protein extract by decanting after which centrifugation takes place. The pH of the extracted protein was adjusted with HCL. It is isoelectric point between 4.0 – 4.3. The precipitate formed was subsequently recovered by centrifugation at room temperature by removing the whey which soluble sugar, residue protein, peptides salt, minor constituents. The resulted curd protein isolated was then dried under air using a desiccator before grinding and sieving took place.

Methods

Seed characteristics

The characteristics were determined following the procedure of Fashakin and Fasanya[10]. The raw seeds were randomly selected and then examined by subjective methods for shape, testa texture, seed colour, eye colour and testa attachment to the cotyledon. The degree of attachment was described as smooth or rough depending on how the seeds appear to the eye.

FUNCTIONAL PROPERTIES OF FLOUR SAMPLES

The functional properties of cowpea flour samples (full fat, defatted, protein isolate) were determined us-

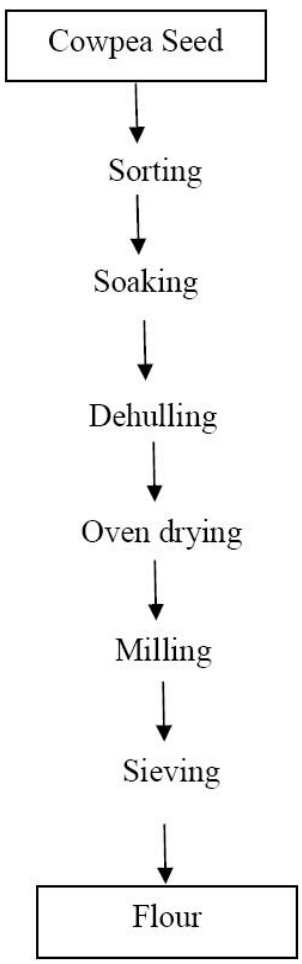

Figure 1 : Flow diagram for the production of dehulled full fat cowpea flour

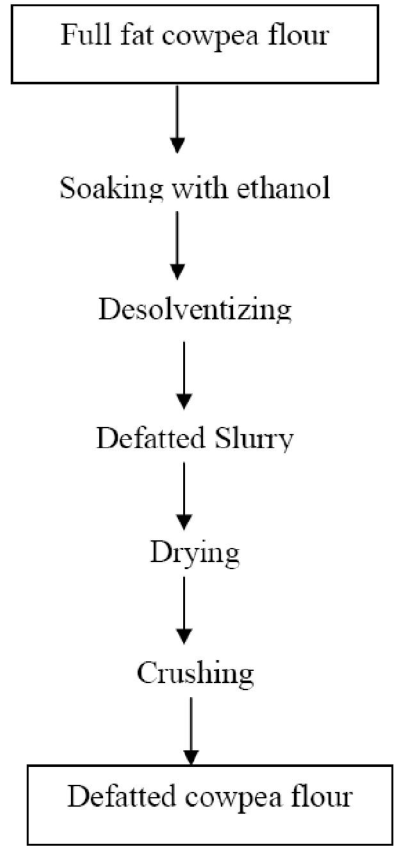

Figure 2 : Flow diagram of commercial processing of defatted cowpea flour

ing the methods specified by Okaka and Potter[7]; Okezie and Bello[2] and Nawansinga Rao (1982).

BULK DENSITY

The method of Okaka and Potter[8] was used. 3 grams of flour sample was measured into a calibrated measuring cylinder. The bottom of the cylinder was tapped repeatedly on a pad placed on a laboratory bench. Tapping was done until there was no further reduction in the volume occupied by the sample. The bulk density was determined as the ratio of the weight of the sample to its volume calculated as shown below.

Bulk density = W/V

Where W = weight of sample in gram; V = volume of sample in cubic centime.

SWELLING INDEX

Swelling index was calculated using the method of Ukpabi and Ndinele (1990). 1 gram of the sample was

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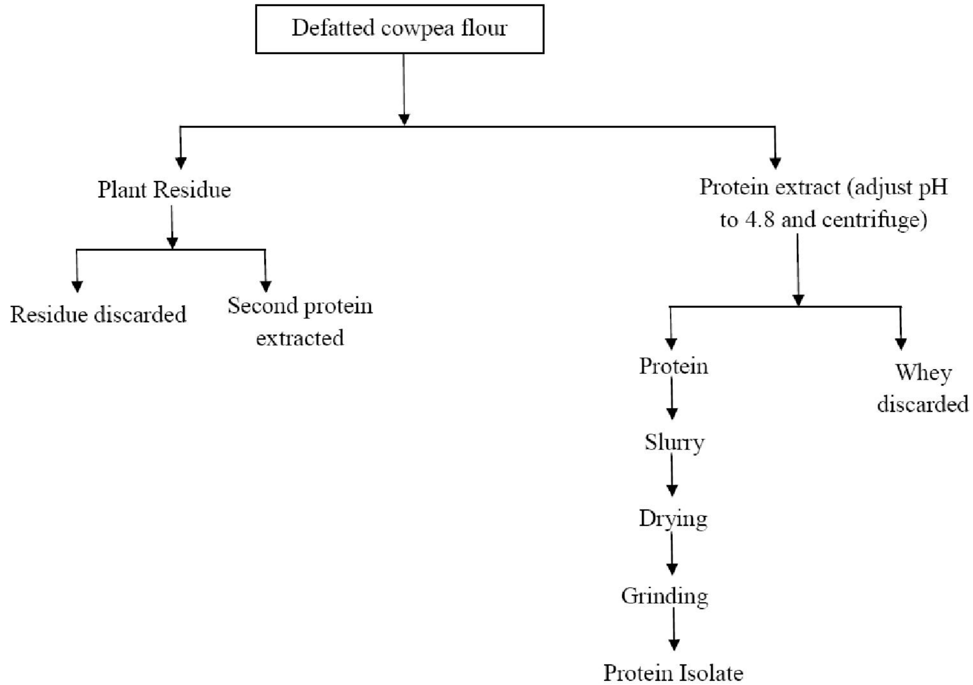

Figure 3 : Flow diagram for the production of isolated protein from defatted cowpea flour

weighed and dispersed into a test tube, leveled and the highest noted. Distilled water (10mls) was added and allowed to stand for 1hour. The height was then recorded and the swelling index calculated as the ratio of the final height to the initial height.

Swelling index = H_2/H_1

Where H_2 = Final height; H_1 = Initial height.

WATER ABSORPTION CAPACITY

This is determined as the weight of water absorbed and held by 1gram of the sample[8]. 1 gram of the sample was weighed and put into a test tube and 10mls of distilled water was added to the sample and mixed well. The mixture was allowed to stand for 30minutes at room temperature. The mixture was centrifuged at 3500rpm for 30minutes. The supernatant was decanted and measured.

Therefore, WAC=$V_1 - V_2$

Where: WAC =Water absorption capacity; V_1=Initial volume of distilled water; V_2=Final volume of distilled water.

OIL ABSORPTION CAPACITY

This was determined in the same way as water absorption capacity. However, a refined vegetable oil was used in place of water and the time allowed for absorption was longer (1hour at room temperature as against 30minutes for water. The oil absorption capacity was determined by differences, as the volume of oil absorbed and holds by 1gram of the sample as shown below.

Oil absorption capacity = (initial volume of oil) – (Final volume of oil)

GELATION CAPACITY

Ten grams (10g) of sample was weighed into a beaker with 27mls of water and heated until gelling point. The temperature at which it gelled was measured using a thermometer.

EMULSION CAPACITY

The method used was done by the method described by Okezie and Bello[2]. 1gram of sample was mixed with 5mls of distilled water in a test tube and shake for 30seconds. 5mls of refined oil was also added and shake continuously until properly mixed. The test tube was left to stand for 30minutes. The height of oil separated from the sample was measured. The emulsion capacity was expressed as the amount of oil emulsified and held per gram of the sample. It is shown below:

Emulsion capacity = (Emulsion height/Water Height) x 100

FOAMING CAPACITY

The method of Nawasinga Rao (1982) was used. 1gram of sample was mixed with 10mls of distilled water and blended for 5minutes. After the resulting mixture, the height of foam was recorded after 30 seconds. The foaming produced after whipping. It is calculated as;

Foaming capacity = $(V_a - V_b)/V_b$ x 100/1

Where V_a = height after whipping; V_b = height before whipping.

WETTABILITY

This was determined as the time (in seconds) taken by a unit weight (1g) of the flour sample to get completely wet on the sample of water under laboratory conditions. The method used was described by Okezie and Bello[2]. About 400mls of water was measured into a clean glass beaker (600mls capacity). With the aid of retort stand, it was arranged such that a clean test tube was clamped in an inverted position over the water in the beaker. The clamped position was adjusted such that the distance from the mouth of the test tube to the surface of water in the beaker was exactly 10cm both the water in the beaker and the clamped position were marked with masking tape.

Subsequently, 1gram of the sample was weighted into the marked test tube and its mouth covered with a thumb. It was carefully inverted over the water and clamped with the retort stand at the marked spot without removing the thumb. With the stop watch, set to read, the thumb was removed and the sample allowed to fall into the water surface as the stop watch was put simultaneously.

The flour samples were observed and the stop watch stopped as the last few samples got wet. This experiment was repeated three times for each sample and the means values taken.

STATISTICAL ANALYSIS

Experimental data were analyzed using analysis of variance (ANOVA) and Duncan's multiple range test were used to determine significantly different means.

RESULT AND DISCUSSION

TABLE 1 shows functional properties of full fat, defatted and protein isolated cowpea flours. Bulk density (BD) was highest in t full fat cowpea flour (1.88g/ml) and lowest in the protein isolated cowpea flour (0.06g/ml). There was a significant difference ($P < 0.05$) in the BD of the cowpea flour samples.

TABLE 1 : Functional properties of full fat, defatted and protein isolate cowpea flours

Sample	BD	WAC	OAC	FC	EC	SI	GT
FF	1.88^a	2.13^c	3.23^b	16.97^a	82.16^b	1.62^c	80.20^b
DF	1.35^b	2.43^b	2.32^c	3.01^c	88.07^a	1.85^b	81.97^a
ISO	0.06^c	3.03^a	5.49^a	33.23^a	46.57^c	3.14^a	0
LSD	0.03	0.16	0.14	0.80	1.24	0.11	0.27

***All values are expressed as mean ± SD of these determinations. Mean values down the columns with different superscriptions are significantly different ($p<0.05$)**

Key: FF = full fat cowpea flour; Df = dehulled full fat cowpea flour; ISO = Isolated protein defatted cowpea flour; BD= Bulk density; WAC= Water absorption capacity; OAC= Oil absorption capacity; FC= Foaming capacity; EC= emulsion capacity; SI= Swelling index; GI= Gelatinization temperature and; LSD= Least significant difference

BULK DENSITIES

Bulk densities of full fat cowpea flour and defatted cowpea flour gave appreciable values of 1.88 and 1.35g/ml, respectively. These values were higher than the previous values of[5] which ranged from 0.69 – 0.80glml. However, BD of protein isolate cowpea flour was lower. High bulk density obtained in the full fat and defatted cowpea flours showed that the flours were heavy. They will occupy less space per unit weight during packaging and this is vice verse for the protein isolated cowpea flour[5]. The low bulk density in the protein isolated cowpea flour makes it easier to transport due to higher weight. The disadvantage of the low bulk density in the protein isolate cowpea flour is that it will occupy greater space and, therefore, would require more packaging material per unit weight which may result to high packaging cost. Padmasshree *et al* (1987) reported that high bulk density is desirable for greater ease of dispensability of flours. The bulk density of flour protein is important in the preparation of infant food formulations. High bulk density, limits caloric and nutrient intake per feed of the child which can result in growth faltering. Low bulk density for flour protein is advantageous for infants as both calorie and nutrient intake is enhanced per feed of the child. Akpata and Akubor[11] reported that low bulk density of flours will be an advantage in the formulation of complementary foods. Protein isolate cowpea flour could be most suitable for production of complementary foods.

Water absorption capacity (WAC) was highest in protein isolate cowpea flour (3.03ml/g) and lowest in full fat cowpea flour (2.13ml/g). These was a significant difference ($p<0.05$) in the WAC of the flour samples. WAC of the flours were higher than the value reported by Chinma *et al.*[3] which ranged from 1.66 to 1.94ml/g, for cowpea varieties in Nigeria.

However, WAC of cowpea flour samples were within the values reported by Appiah *et al.*[5] which range from 1.89±0.02 – 2.15±0.03ml/g for cowpea varieties in Ghana. The highest WAC obtained protein isolate cowpea flour confirms with the report of Butt and Batool[12] that the ability of protein to bind water is indicative of its water absorption capacity. Also, the observed variation in WAC among the cowpea flours may be attributed to different protein concentration, their changes of interaction with water and their conformational characteristics[12]. Low WAC in flours is due to less availability of polar amino acids,[5]. WAC is useful in food systems such as processed cheese, sausage and bakery products which require hydration to improve handling quality.

Oil absorption capacity (OAC) was highest in protein isolate cowpea flour (5.49ml/g) and lowest in defatted cowpea flour (2.32ml/g). There was a significant different ($p<0.05$) in the WAC of the flour samples. OAC of the cowpea flour samples obtained in the study were higher than 0.39±0.053ml/g reported for some Nigerian cowpeas[3] and that reported for Ghana cowpea which ranged from 1.95±0.03 to 2.31±0.06ml/g[5].

Foaming capacity (FC) was highest in protein isolate cowpea flour (33.23%) and lowest in defatted cowpea flour (3.01%). There was a significant differences ($p<0.05$) in the FC of the cowpea flour samples. FC of full fat cowpea flour was close to the 17.0±0.06ml of Adom cowpea. FC of protein isolate cowpea flour was lower than the 10.00±0.07 to 21.00±0.06ml of flours of cowpea varieties. FC of isolate cowpea flour was appreciably higher than the previously reported values by Appiah *et al.*[5]. Foam capacity is determined by measuring an increase in foam volume upon the introduction of a gas into a protein dispersion protein. Foams are important in many processes in the beverage and food industries and this has stimulated interest in their formation and stability. They are used to improve texture, consistency and appearance of foods. In food system, foams are found commonly in baked confectionary and other goods. Foam formation and functions depends on the type of protein, pH, processing methods, viscosity and surface tension.

Emulsion capacity (EC) was highest in defatted cowpea flour (88.07%) and lowest in protein isolate cowpea flour (46.57%). There was a significant difference ($p<0.05$) in the EC of the cowpea flour samples. Emulsion capacity measures the maximum oil addition until phase separation occurs. The efficiency of emulsification by seed proteins varies with the type of protein, its concentration and solubility, pH, ionic, strength, viscosity of the system, temperature and method of preparation of the emulsion.

Swelling index (S.I) was highest in protein isolate cowpea flour (3.141) and lowest in full fat cowpea flour samples. The high swelling index observed in protein isolate cowpea flour showed that it could be useful in food systems where swelling is required[5]

Gelatinization temperature (G.T) was highest in defatted cowpea flour, (81.97^{o}C) lower in full fat cowpea flour (80.2^{o}C). Gelatinization was not discovered in protein isolate cowpea flour. Gelation is an important structural and rheological property of flour proteins. It is a measure of the charge in consistency of the protein solution when heated at a certain temperature for a given period of time. Gels enhanced the body and texture of a product and their primary function in foods such as meat curds, cheeses is to bind or solidity the free water in the foods. The ability of a protein to form a gel depends on the type and method of preparation of the protein, its concentration, the rate of heating and cooling, pH and the presence of salts and reducing agents. High protein concentration is required for the gelation of globular proteins while seed coat fraction in flour proteins interfere with the formation of gels.

EFFECTS OF TEMPERATURE

Effect of temperature on the water absorption capacity (WAC) of full fat, defatted and protein isolated cowpea flour are shown Figure 4. WAC of full fat cowpea flour was highest at temperature of 40°C (2.10ml/g) and lowest at 70°C (0.6ml/g). WAC of full fat cowpea flours were 1.7ml/g and 1.4ml/g at 50°C and 60°C, respectively. WAC of defatted cowpea flour was lowest at 70°C (1.2ml/g) and highest at 40°C (2.5ml/g). WAC of protein isolate cowpea flour was highest at temperature of 40°C (3.0ml/g) and lowest at 70°C (1.3ml/g). WAC of protein isolate cowpea flour was 2.4ml/g and 1.6ml/g at 50°C and 60°C, respectively. The trends of the graphs showed that increased in temperature, decrease in water absorption capacity. This was generally observed in full fat and protein isolate cowpea flours. Effect of temperature on foaming capacity (FC) of full fat, defatted and protein isolate cowpea flour are shown in Figures 5. FC was lowest at temperature of 70°C (0.5%) and highest at 40°C (1.90%). FC of full fat cowpea flour were 1.0% and 0.7% and 60°C and 70°C Co.2% and highest at 40°C and 50°C (0.30%) FC of isolated cowpea flour was ml at temperature of 70°C and highest at 40°C (3.50%). The trends of the graphs in the study showed that increase in temperature caused decrease in foaming capacity of full fat, defatted and protein isolate cowpea flours. Effect of temperature on the swelling index (S.I) of full fat, defatted and protein isolate cowpea flours are shown in Figure 6. Swelling index was highest at temperature of 40°C (1.69) and lowest at 70°C (1.50). S.I. was 1.63 and 1.67 at temperature of 50°C and 60°C, respectively. S.I. of defatted cowpea flour was highest at temperature of 40°C (1.81) and lowest at 70°C (1.56). S.I. of defatted cowpea flour were 1.8 and 1.63 at temperature of 50°C and 60°C, respectively. S.I. of protein isolate cowpea flour was highest at temperature of 40°C (3.05) and lowest at 70°C (2.0). S.I. of isolate protein cowpea flours were 2.16 and 2.11 at temperatures of 50°C and 60°C respectively. Generally, the study showed that increase in temperature caused decrease in FC of full fat, defatted and protein isolate cowpea flours. The study showed that increase in temperature reduces WAC, FC and S.I. of cowpea flours and this confirms with the report of Enwere and Ngoddy[14] that hydrothermal treatment (60°C and 120°C) applied to cowpea seeds priors to

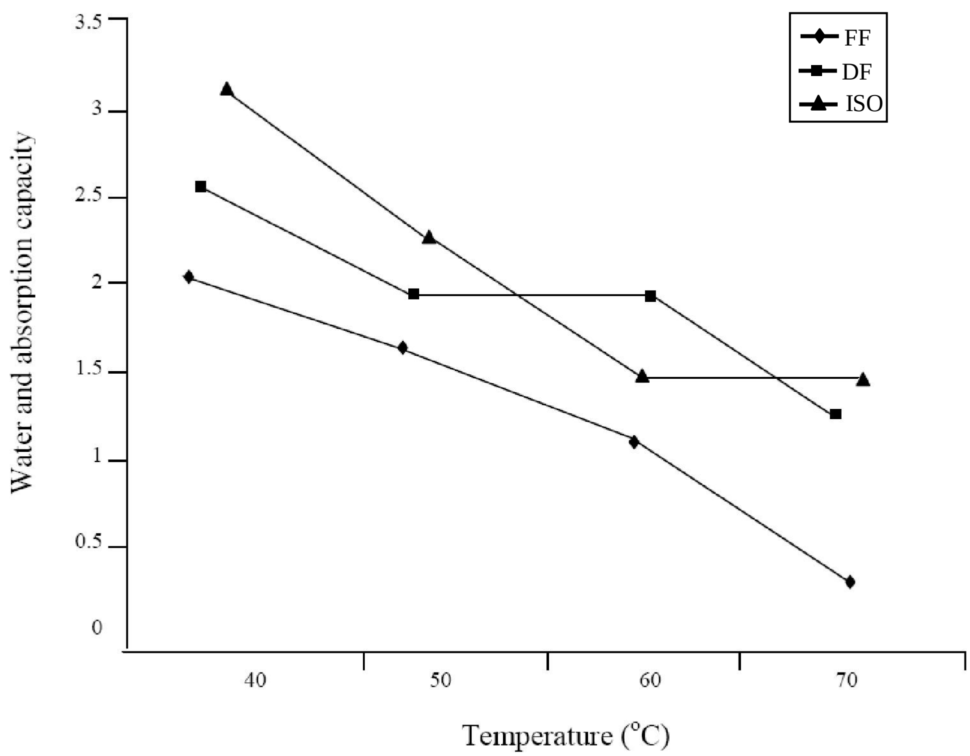

Figure 4 : Effect of temperature on water absorption capacity of full fat, defatted and protein isolate cowpea flours

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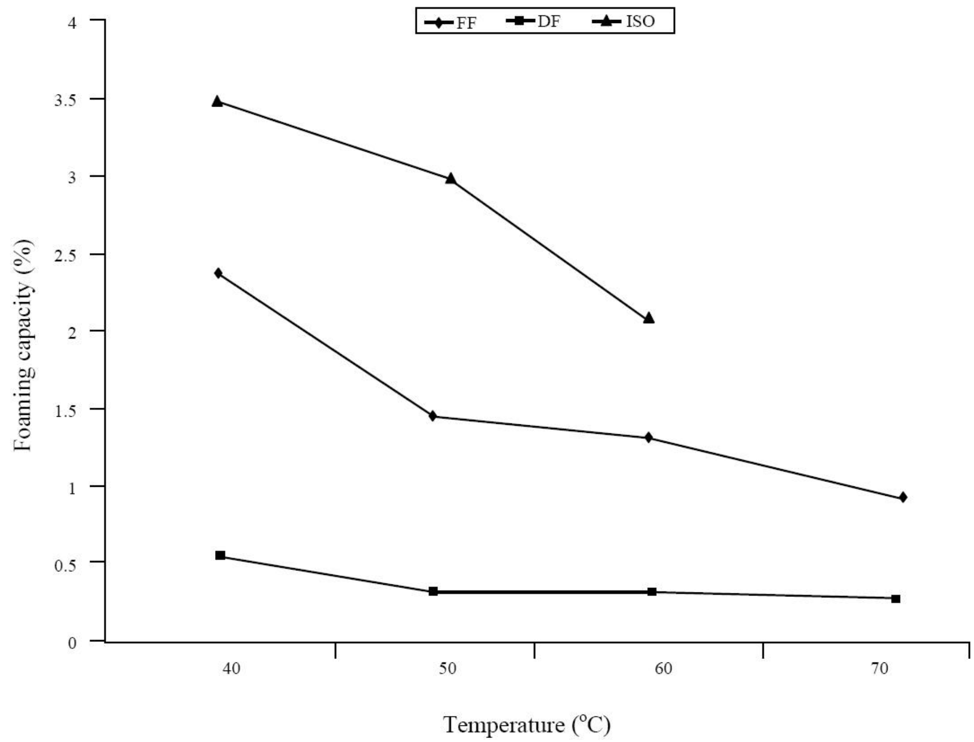

Figure 5 : Effect of temperature on foaming capacity of full fat, defatted and protein isolate cowpea flours

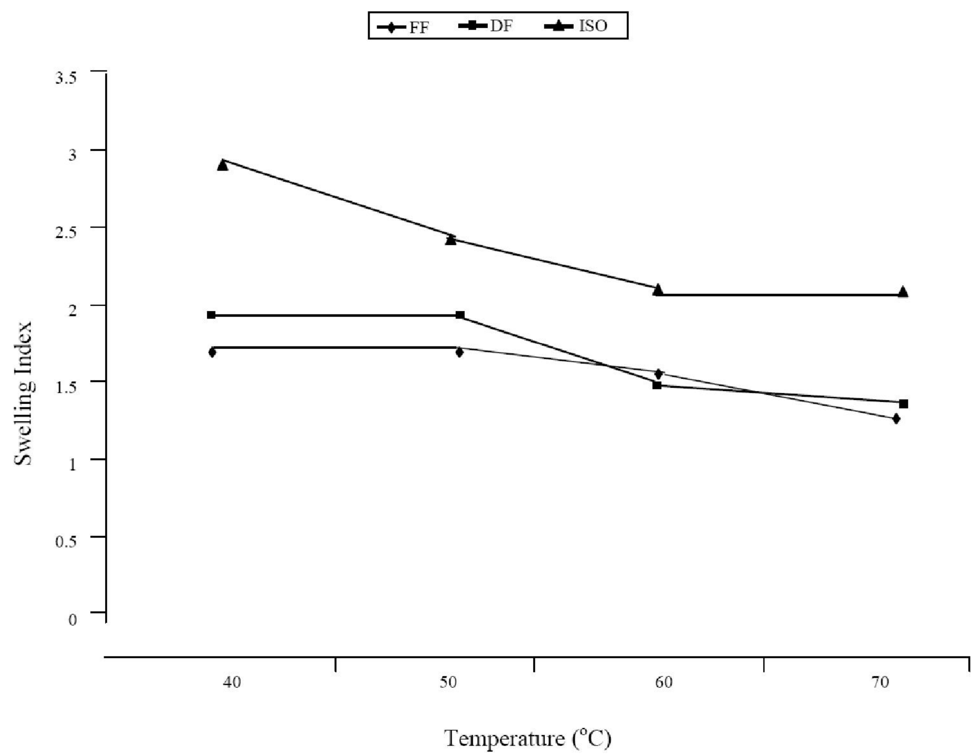

Figure 6 : Effect of temperature on swelling index of full fat, defatted and protein isolate cowpea flours

milling decreased essential functional properties such as nitrogen solubility, water absorption, and swelling and foaming capacities. The initial temperature for 16hrs at 30°C did not alter any selected functional properties of the flour. Henshaw and Lawal[6] reported that wet dehulling during processing reduced foaming capacity as a result of loss of protein in soak water. They also reported that excessive heat lowered nitrogen solubility and foaming capacity.

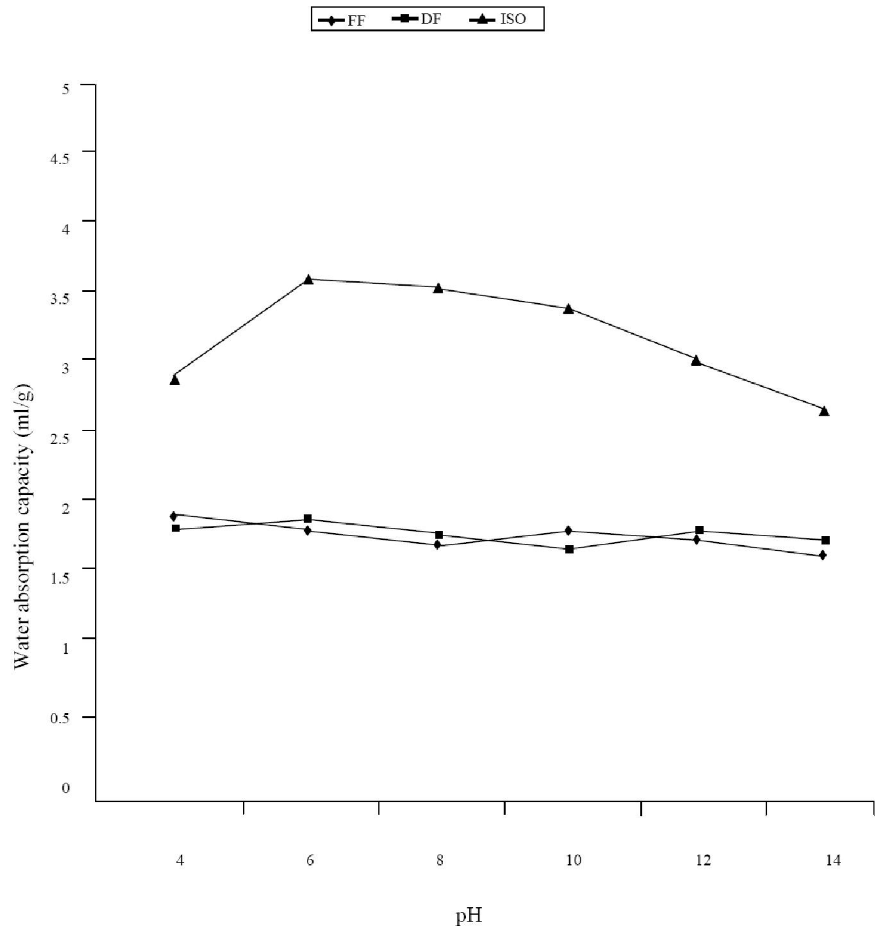

Figure 7 : Effect of pH on water absorption capacity of full fat, defatted and protein isolate cowpea flours

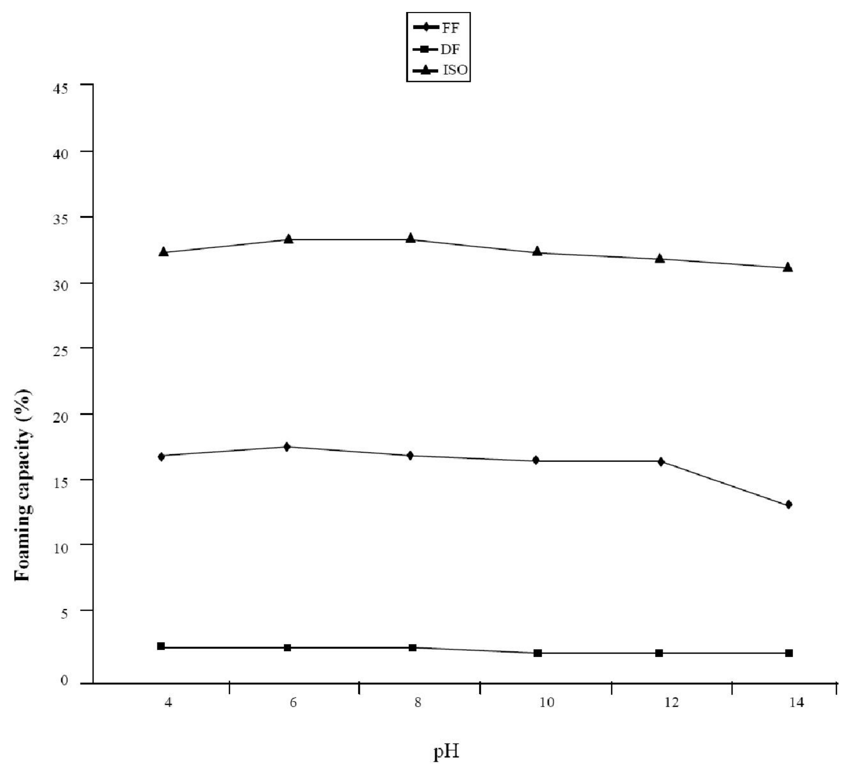

Figure 8 : Effect of pH on water foaming capacity of full fat, defatted and protein isolate cowpea flours

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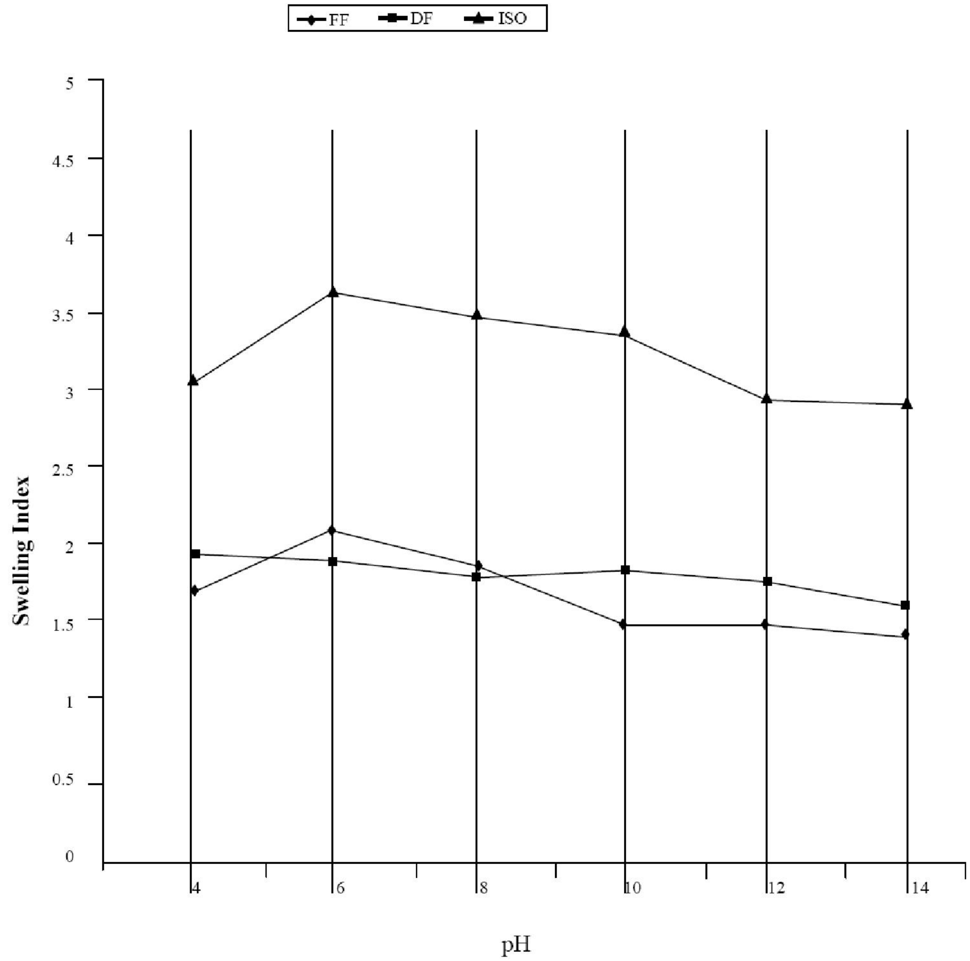

Figure 9 : Effect of pH on swelling index capacity of full fat, defatted and protein isolate cowpea flours

Appendix 1

EFFECT OF pH

Effect of temperature on water absorption capacity

Sample	40	50	60	70	Total	Means ± SD
FF	2.10	1.7	1.4	0.6	5.8	1.425[c] ± 0.68
DF	2.50	2.1	1.9	1.2	7.7	1.925[b] ± 0.54
ISO	3.00	2.4	1.6	1.3	8.3	2.08[a] ± 0.77
Total	7.60	6.2	4.9	3.1		
Mean	2.53	2.07	1.63	1.03		
S.D	±0.45	±0.35	±0.25	±0.38		

The anova procedure on water absorption capacity

Source	DF	Sum of Square	Means Square	F value	Pr > 7
Model	2	1.26000000	0.63000000	94.50	<.0001
Error	6	0.04000000	0.006666		
Corrected total	8	1.30000000	67		

R = square: 0.969231; Coeff Var: 3.223013; ROOT MSE: 0.081650; WAC Mean: 2.533333

Effect of pH on the water absorption capacity of full fat, defatted and protein isolate cowpea flours are shown in Figure 7.

High WAC was observed at alkaline pH of 8 and 10 (2.4ml/g) pH at acidic medium of 4 and 6 gave WAC values of 2.1ml/g and 2.2ml/g, respectively. Alkaline pH of 14 gave the lowest value of WAC (1.8ml/g) defatted cowpea flour showed that high WAC was observed at alkaline pH 8 (2.5ml/g) while lowest WAC was observed at acidic pH of 4(2.0ml/g). WAC at pH value of 6, 10, 12 and 14, were 2.3ml/g, 2.3ml/g, 2.1ml/g and 2.1ml/g, respectively.

Protein isolate cowpea flour showed that WAC was higher at acidic pH of 6 (4.3ml/g) and lower at acidic pH of 4(3.1ml/g). Effect of pH on foaming capacity (FC/or full fat, defatted cowpea flour showed that FC was highest at alkaline pH of 14 (4.50%) and lowest at acidic pH of 4 and 6 (2.7%). Isolated protein cowpea flour showed that FC was highest at alkaline pH of 14

(40.37%) and lowest at acidic pH of 4(33.03%). Effect of pH on swelling index (S.I) of full fat cowpea flour was highest at alkaline pH of 8 (2.13) and lowest at alkaline pH of 14 (11.75).

Appendix 2

Appendix 3

Effect of temperature on foaming capacity

Sample	40	50	60	70	Total	Means ± SD
FF	1.9	1.0	0.7	0.5	4.1	$1.025^{b} \pm 0.62$
DF	0.3	0.3	0.2	0.2	1.0	$0.250^{c} \pm 0.06$
ISO	3.5	3.25	1.8	0	8.6	$2.138^{9} \pm 0.61$
Total	5.7	4.55	2.7	0.7	LSD	(0.05%) = 0.02
Mean	1.90	1.52	0.90	0.23		
S.D	±1.6	±1.54	±0.82	±0.25		

The anova procedure on foaming capacity

Source	DF	Sum of Square	Means Square	F value	Pr > 7
Model	2	1372.842867	686.421433	4331.95	<.001
Error	6	0.950733	0.158456		
Corrected total	8	1373.793600			

R = square: 0.999308; Coeff Var: 2.244304; ROOT MSE: 0.398065; WAC Mean:17.73667

Effect of temperature on swelling index capacity

Sample	40	50	60	70	Total	Means ± SD
FF	1.6	1.63	1.67	1.5	6.40	$1.60^{b} \pm 0.07$
DF	1.81	1.8	1.63	1.56	6.80	$1.70^{b} \pm 0.12$
ISO	3.05	2.61	2.11	2.0	9.77	$2.44^{a} \pm 0.48$
Total	6.46	6.04	5.41	5.06	LSD	(0.05%) = 0.26
Mean	2.15	2.01	1.80	1.69		
S.D	±0.78	±0.52	±0.27	±0.27		

The anova procedure on swelling index capacity

Source	DF	Sum of Square	Means Square	F value	Pr > 7
Model	2	4.04615556	2.02307778	679.39	<.0001
Error	6	0.01786667	0.00297778		
Corrected total	8	4.0642222			

R = square: 0.995604; Coeff Var: 2.475409; ROOT MSE: 0.054569; WAC Mean: 2.204444

CONCLUSION AND RECOMMENDATION

The study showed the full fat, defatted and protein isolate cowpea flours gave good functional properties which could be exploited for food formulation. They can be used as composites or blends with conventional flours which are low in protein. The study recommends the utilization and promotion of the cowpea flours as this can go a long way to alleviate protein malnutrition and food insecurity.

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