Proximate Composition, Mineral Content & The Effect of Ethylene Glycol and Ethanol (Non-Aqueous Solvents) on The Functional Properties of Protein Concentrates of Gourd Melon (Citrullus colocynthis l.) Seed.

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Abstract— Determination of proximate composition, mineral content, and the effect of ethylene glycol and ethanol at varied pH on the functional properties using standard methods were carried out on the protein concentrates of two samples of Gourd Melon *(Citrullus colocynthis L.)*, one containing hull and the other without hull. Results for the proximate composition for the sample without hull gave 3.99% Moisture Content, 5% Ash Content, 16.455% Fat Content, 52.875% Crude Protein, 6.855% Crude Fibre and 10.342% for Carbohydrate by Difference. Also the results for the proximate composition of sample containing hull gave 5.09% Moisture Content, 7% Ash Content, 19.835% Fat Content, 45.313% Crude Protein, 20.40% Crude Fibre and 6.842% Carbohydrate by Difference. The results for the two samples showed that sample containing hull is richer in Na, Ca and K. The Least Gelation Concentrations for both samples were studied at different concentrations of ethylene glycol-water and ethanol-water mixtures. The Solvent Absorption Capacity and the Oil Absorption Capacity of the two samples were also studied in different concentrations of the two different solvent mixtures. Solvent Absorption Capacity was found to be higher in ethanol-water than in ethylene glycol-water, and also higher in sample containing hull than the sample without hull. The Oil Absorption Capacity of sample without hull was found to be less than sample containing hull. It was also found that the Oil Absorption Capacity of the two samples is higher in ethylene glycol-water than in ethanol-water mixtures. Emulsion Capacity, Emulsion Stability, Foaming Capacity, Foaming Stability were investigated in different concentrations of ethylene glycol-water and ethanol-water mixtures for the two different samples under standard conditions. Foaming Capacity (FC) for both samples increased with increasing concentration of ethylene glycol-water and ethanol-water mixtures, while Emulsion Capacity (EC) for the two different samples decreased with increasing solvent concentration. The Emulsion Capacity (ES) for booth samples were nearly constant.

The Protein Solubility of the two different samples (sample containing hull and sample without hull) were investigated at different pH in different concentrations of ethylene glycol-water and ethanol-water mixtures. The results indicated that non-aqueous solvent has effect on the functional properties of the samples.

Keywords— Proximate composition, mineral content, ethylene glycol , ethanol, Citrullus colocynthis, protein, Least Gelation concentration, Fibre, Fat, Carbohydrate, moisture content, Ash content, Solvent Absorption, Oil Absorption, Emulsion, Foaming.

1. INTRODUCTION

Citrullus colocynthis (Gourd Melon) is found to be part of the *Cucurbitaceae* family. The melon seed crop is grown in wet humid climate, mostly in the South western Nigeria, West Africa like Ghana, Benin, Togo, and in the Middle East [25]. Several analyses carried out by researchers and food scientists on melon (undefatted seeds) show that the seed contains about 40 – 55 percent oil, 30 – 45 percent protein [13]. It has been reported that the seed is a valuable source of dietary protein [8],[23], which also contains carbohydrate and minerals, making it a complete food. It has also be found to be of great medicinal use such as antioxidant, antidiabetics etc. Harnessing plant protein sources in dietary and food formulation is based on the knowledge of their nutritional composition and functional properties [16]. Considering the fact that melon seeds

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contain high amount of protein, it is therefore of great importance to concentrate the melon and fully utilize them as protein supplements in food formulation and for other applications in the food industry [14].

Citrullus colocynthis L. seeds are rich in Sodium (Na), Calcium (Ca), and Potassium (K), which make them useful as food supplements where there is deficiency of these elements, or when they are needed in large amount in dietary. Toxic elements are relatively absent, but a trace of cadmium (Cd) was found to be present in the hull. This research work also shows that it contains small amount of Iron (Fe) and Magnesium (Mg) which are of good nutritional values.

The functional properties of proteins refer to their physical and chemical properties which strongly affect their behaviour in food systems during processing, preparation, storage and consumption, which if not properly optimized, negatively influence and reduce their quality and organoleptic attributes in food [10]. One of the problems associated with melon is the variation in viscosity (low viscosity) of their doughs, because it results in soft dough, causing lower energy transfer during food processing. Therefore, it is necessary to improve their viscosity and other functional properties by monitoring the effect of non-aqueous solvents such as ethanol and ethylene glycol on the flour.

Based on the above facts and problems associated with protein, the aim of this project is then centred on the optimization of the functional properties of the protein concentrate of *Citrullus colocynthis*, studying the potential effect of non-aqueous solvents (ethylene glycol and ethanol) on the protein concentrate, which will in turn improve their behaviour in food system during preparation, processing, storage and consumption.

The objectives of this work are to:

(i) Carry out the analysis of the proximate composition on the protein concentrate of *Citrullus colocynthis* Seed flour (sample containing hull and sample without hull).

(ii) Carry out analysis on mineral content of the aforementioned samples, and to

(iii) Study the effect of ethylene glycol-water and ethanol-water mixtures on the functional properties of the protein concentrate of both samples containing hull and the one without hull.

2.0 MATERIALS AND METHODS

2.1 MATERIALS

Two different samples of *Citrullus colocynthis* (melon) seeds, one with hull, and the other without hull, were purchased from a local market (Oja Oba) in Akure, Ondo State of Nigeria. The samples were prepared for further analysis.

2.1.1 PREPARATION OF SEED FLOUR

The two samples, one with hull (shell), and the other without hull were screened to remove stones and other impurities. The samples were dried in the oven to remove moisture, and were milled and blended to fine seed flour using miller and blender. The seed flour were packaged in polyethylene containers and stored in the refrigerator for further analysis.

2.1.2 PREPARATION OF PROTEIN CONCENTRATE (DEFATTED SAMPLES)

Sample flours were defatted using Petroleum Ether (Solvent) on a soxhlet apparatus at 60^0C for about 5hours. The defatted samples (fat free) left were allowed to dry and packaged in polyethylene containers and stored in the refrigerator for subsequent analyses.

2.2 PROXIMATE ANALYSIS

2.2.1 MOISTURE CONTENT DETERMINATION

The moisture content was determined by using oven-drying method. Clean and dry Petri-dishes were weighed by using electronic weighing balance and their respective weights were recorded (W_1). 3g of each sample were weighed into the dishes (W_2) and transferred into the oven at 105ºC and dried for about three hours, after which they were transferred to the desiccator to cool and then re-weighed until constant weights (W_3) were obtained [2].

$$\% \text{ moisture} = \frac{\text{loss of weight due to drying}}{\text{Weight of Sample taken}} \times \frac{100}{1}$$

$$\% \text{ moisture} = \frac{W2-W3}{W2-W1} \times \frac{100}{1}$$

2.2.2 ASH CONTENT DETERMINATION

1g each of finely ground sample (with hull and without hull) were weighed into clean, dried pre-weighed crucibles (W_1). The organic matter was burned off until the sample became charred. The crucibles were then transferred to the muffle furnace set at 550ºC. Ashing was continued until a light grey or white ash was obtained.

The crucibles were then cooled in a desiccators and weighed (W_2) [2].

$$\% \text{ Ash} = \frac{W2-W1}{\text{Weight of Sample taken}} \times \frac{100}{1}$$

2.2.3 FAT DETERMINATION

Cleaned and dried filter paper was weighed as (W_1) and about 2g of dried sample was added and reweighed (W_2). Round bottom flask was filled with petroleum ether (60ºC) up to 3/4 of the flask. The Soxhlet extractor was fixed with a reflux condenser and adjust the heat source so that the solvent boils gently. The samples were put inside the thimble and inserted into the soxhlet apparatus and extraction under reflux was carried out with petroleum ether (60ºC). After the barrel of the extractor is empty the condenser was removed and the thimble was removed,

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taken into the oven at 100°C for one hour and later cooled in the desiccators and weighed again (W_3), [2].

$$\% \text{ fat } = \frac{\text{weight loss of sample (extracted fat)}}{\text{Original weight of sample}} \times \frac{100}{1}$$

$$\% \text{ fat} = \frac{W2-W3}{W2-W1} \times \frac{100}{1}$$

2.2.4 CRUDE PROTEIN DETERMINATION

0.5g of the samples was weighed into the micro kjeldahl digestion flask and one tablet of selenium catalyst and 5ml of concentration H_2SO_4 were added. The mixture was digested on an electrothermal heater until clear solution was obtained. The flask was allowed to cool after which the solution was diluted with distilled water to 50ml and 5ml of this was transferred into the distilled apparatus. 5ml of 2% boric acid was pipette into a 100ml conical flask (the receiver flask) and three (3) drops of screened methyl red indicator were added. 40% NaOH was continually added to the digested sample until the solution turned cloudy which indicated that the solution had become alkaline. The distillation was carried out into the acid solution in the receiver flask with the delivery tube below the acid level. As distillation was going on, the pink colour solution of the receiver flask turned blue indicating the presence of ammonia. Distillation was continued until the content of the round bottom flask was about 50ml after which the delivery of the condenser was rinsed with distilled water. The resulting solution in conical flask was then titrated with 0.1M HCl [2].

$$D_f \text{ (Dillution factor)} = \frac{50 \text{ (ml of sample + distilled water)}}{10 \text{ (ml of sample)}} = 5$$

$$\% \text{ Nitrogen} = \frac{\text{Titre Value x 0.1M HCl x 0.014 x 100 x df}}{\text{Original weight of sample used}}$$

% Crude protein= % Nitrogen x protein conversion factor (6.25).

2.2.5. CRUDE FIBRE DETERMINATION

2.0g (W_1) of the sample was weighed into one litre conical flask. 200ml of boiling 1.25% H_2SO_4 was added and boiled gently for 30minutes. The mixture was filtered through a muslin cloth and rinsed well with hot distilled water. The sample was scrapped back into the flask with spatula and 200ml of boiling 1.25% NaOH was added and allowed to boil gently for 30minutes. It was furthermore filtered through the muslin cloth and the residue was washed thoroughly with hot distilled water, rinsed once with 10% HCl, and twice with Petroleum ether to remove any residual fat. The residue was then scraped into a dry cleaned crucible, placed in the oven to dry at a temperature of 105°C, cooled in a desiccator and weighed (W_2). The weighed residue was placed in the muffle furnace at 550°C for 90minutes. The ash was cooled in the desiccator and re-weighed (W_3) [9].

$$\% \text{ Crude Fibre } = \frac{W2-W3}{W2-W1} \times \frac{100}{1}$$

2.2.6 DETERMINATION OF SOLUBLE CARBOHYDRATE (NITROGEN FREE EXTRACT – NFE)

The Nitrogen Free Extract (NFE) is referred to as soluble carbohydrate and is determined by difference.

% NFE = 100% - (% Ash + % Crude Fibre + % Crude Fat + % Crude Protein + Moisture Content).

2.3. MINERAL CONTENT DETERMINATION

The ash was dissolved in 20ml of 10% HCl and made up to the mark 100ml standard flask with distilled water. The solutions were then filtered using filter paper and the filtrates which contain dissolved minerals were transferred into 120ml polyethylene bottles for analyses. The mineral contents of the samples were analysed with the aid of Atomic Absorption Spectrophometer (AAS-Bulk Scientific 210VGP) and Flame Photometer (FP 902PG) in analysis of Na and K.

2.4. FUNCTIONAL PROPERTIES OF PROTEIN

The various functional properties of protein are; Water or Solvent Absorption Capacity (SAC), Foaming Capacity (FC) and Stability, Oil Absorption Capacity (OAC), Emulsion Capacity (EC) and Stability, Protein Solubility, Bulk Density, and Least Gelation Concentration. These properties affect the behaviour of protein during processing, consumption and storage.

2.4.1 DETERMINATION OF LEAST GELATION CONCENTRATION

The modified procedure of Coffman and Garcia, 1977 [4] was used to determine the gelation properties of the two protein samples. Appropriate sample suspensions of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 were prepared in 5ml of distilled water (0% EG and 0% Ethanol). The test tubes containing these suspensions were heated for one hour in a water bath at 100°C, followed by rapid cooling in water at ordinary room temperature. The test tubes were subsequently cooled for 2hours in cold water (at 4°C). The least gelation concentration was taken as the concentration at which the sample from the test tube did not slip or fall when inverted.

Note that for different concentrations of ethylene glycol – water and ethanol – water mixtures, the same procedure was repeated respectively.

2.4.2. DETERMINATION OF FOAMING CAPACITY AND STABILITY

The method of Coffman and Garcia (1977), [4] was employed in the study of foaming capacity and stability with slight modification. 0.4g of sample was whipped in 20ml of distilled water (0% EG and Ethanol) for 5minutes in an electric blender at a speed set at "Wax" and the foaming sample was poured into a 100ml measuring cylinder. The total volume after whipping was measured at time interval 0.00, 0.25, 0.50, 1.00 and 3.00 hours to determine the foaming capacity and stability. The volume measured at time interval 0.00 hour was used to determine the foaming capacity.

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$$\% \text{ Volume Increase} = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} X \frac{100}{1}$$

The procedure was repeated for the different concentration of ethylene glycol-water and ethanol-water mixtures respectively.

2.4.3. DETERMINATION OF SOLVENT ABSORPTION CAPACITY

The solvent absorption capacity of the defatted sample was determined by Sathe and Salunkhe (1982) procedure [24] with slight modification. 5ml of water was added to 0.5g of the sample in the centrifuge tube. The sample solution was stirred vigorously four times with glass rod. The sample solution was then centrifuged for 25minutes at 3500rpm (revolutions per minute). The percentage solvent absorbed was calculated. The same procedure was repeated for the various concentration of Ethylene glycol (EG) -water and ethanol-water mixtures respectively.

$$\% \text{ Weight of Solvent} = \frac{\text{Volume of Solvent Absorbed}}{\text{Weight of Sample}} \text{ x } \frac{100}{1}$$

2.4.4. DETERMINATION OF OIL ABSORPTION CAPACITY

Sathe and Salunkhe (1982) method [24] was also employed in the determination oil absorption capacity with slight modification. To 0.5g of sample contained in a centrifuge tube was added 5ml of water, followed by addition of 3ml of Executive Oil (S.G = 0.938). The mixture was stirred using glass rod in order to disperse the sample in both the oil and the water. The sample mixture was allowed to stand for 30minutes after which was centrifuged to clearly distinguish between the two layers (oil and water). The volume of oil was obtained using a syringe (pipette). The density of oil was calculated and the oil absorption capacity was expressed as percentage oil bound or absorbed by 1g of the sample. The procedure was repeated for various concentrations of the different solvent mixtures.

Density of Oil =0.938g/ml

Specific Gravity of Executive Oil Used = 0.938

Mass of Oil Absorbed = Density of Oil x Volume of Oil Absorbed per gram of sample.

2.4.5. DETERMINATION OF EMULSION CAPACITY AND STABILITY

0.5g of the sample was weighed into a 100ml beaker and 5ml of distilled water was added. The sample solution was stirred for 5 minutes using a magnetic stirrer, after which 3ml of oil was added and stirred for additional 10 minutes. The emulsion was transferred to a centrifuge tube where it was boiled at 80^0C for 15 minutes in a water bath and then cooled for 15 minutes in a water maintained at room temperature. The sample was finally centrifuged at 3500 rpm until the volume of oil separated from emulsion was constant. The same was done for 5%, 10%, 15%, 20%, 25% EG-water and Ethanol-water mixtures respectively. Emulsion stability was monitored and determined after 48hours (2days).

$$\% \text{ Oil Emulsified} = \frac{\text{Volume of Oil Absorbed}}{\text{Initial Volume of Oil Used}} \text{ x } \frac{100}{1}$$

2.4.6. DETERMINATION OF PROTEIN SOLUBILITY

The protein solubility of *Citrullus Colocynthis* at different solvent concentrations and pH were studied. 0.2g each of the samples were suspended in 10ml of distilled water and pH adjusted to the desired value ranging from pH1 to pH12 with 0.1M HCl/NaOH. The suspension was centrifuged at room temperature for 5min at 3500rpm. 0.2ml of the supernatant obtained was used for protein solubility. 2ml of alkali copper solution was added and left to stay for 10 minutes followed by addition of 0.5ml folin reagent to the solution. It was then allowed to stand for 1hour after which the protein was determined using Lowry method with standard Bovine Serum Albumin (BSA) and read against the blank @700nm [22]. The absorbance of the various protein solutions of different concentrations and at different pH were measured using AJ–IC03 UV/VIS Spectrophotometer, and the concentrations extrapolated from a standard BSA curve.

The Lowry method is a convenient assay for large numbers of samples of relatively soluble proteins unlike the Kjeldahl method which is not a rapid or convenient assay, though useful for the determination of the amount of protein in crude sample mixtures.

2.4.7. DETERMINATION OF BULK DENSITY

The bulk density of the two samples were obtained by weighing 1g of the sample (W) and transferred into a dry, transparent 10ml measuring cylinder. The measuring cylinder was tapped at the bottom and sides respectively to ensure even distribution of the sample within the measuring cylinder. The volume of the sample was measured on the graduated cylinder and the bulk density calculated as the ratio of the weight to volume of the sample.

$$\text{Bulk Density} = \frac{\text{Weight of Sample (W)}}{\text{Volume of the same Sample}}$$

3.0. RESULTS AND DISCUSSION

The results of the proximate analysis of *Citrullus colocynthis L.* (Table 4.1) showed that the protein content of this class of melon is high (52.875% and 45.313%) for both samples without hull and with hull respectively. As compared with the protein content of other species of melon such as defatted *C. vulgaris* - 50.93% [23]. From the result in (Table 4.1), it is evident that the protein content of the melon containing hull is slightly lower than that without hull, which is attributed to the contribution of the hull to the volume of the melon.

The moisture content of the two samples (samples without hull and sample with hull), 5.09% and 3.99% respectively as shown in Table 4.1 is low compared to those reported for legumes by [3], which range between 7.0 - 10%. However these values are in agreement with those

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reported by [19], for white melon, pumpkin and water melon seeds which were between 5 - 10%. The moisture content of the sample with hull is lower than that of the sample without hull. This may owe to the fact that the hull (fibre) is mainly made up of organic components which contains hydrophobic group and are capable of repelling water molecules.

According to Table 4.1, the ash content for sample without hull which defines the inorganic residue was given by 5.0% and is lesser than sample containing hull (7.0%). The fat content of the defatted samples without hull and with hull were 19.835% and 16.455% respectively. This shows that the fat content of the sample containing hull is greater than that without hull which is as a result of the high bulk density in sample without hull.

Results from the Table 4.1 shows that the fibre content of sample with hull (20.40%) is much greater than the sample without hull (6.855%).

TABLE 4.1. PROXIMATE COMPOSITIONS AND MINERAL CONTENTS OF THE PROTEIN CONCENTRATE.

COMPONENTS	SAMPLE WITHOUT HULL - A (%)	SAMPLE WITH HULL – B (%)	MINERAL CONTENTS(ELEMENTS)	SAMPLE WITHOUT HULL - A (mg/100g)	SAMPLE WITH HULL – B (mg/100g)
Moisture Content	5.09 + 0.05	3.99 ± 0.07	Na	35.20	40.90
Ash Content	5.0 ± 0.10	7.0 ± 0.12	Ca	60.30	76.10
Crude Fat	19.838 ± 0.28	16.455 ± 0.26	K	40.30	45.12
Crude Protein	52.875 ± 0.02	45.313 ± 0.01	Cd	(BDL)	0.02
Crude Fibre	6.855 ± 0.10	20.40 ± 0.13	Mg	7.02	5.95
Carbohydrate by difference	10.342 ± 0.12	6.842 ± 0.02	Mn	0.40	0.35

Values were obtained by means of triplicate determination while the standard errors were computed using SPSS 17 (Statistical Package); BDL = Below Detection Limit. Instrument Used: Atomic Absorption Spectrophotometer (AAS-Bulk Scientific 210VGP) and Flame Photometer (FP 902PG).

This greater value obtained in sample with hull is as a result of the presence of the hull in the sample which is purely fibre. The fibre content obtained for sample without hull corresponds to that which was obtained by Penuel et. al. (2012), [23] for Guna seed (*Citrullus vulgaris*). The carbohydrate content of sample without hull (10.342%) is more than the content obtained in sample containing hull (6.842%).

The mineral contents of the two samples in mg/100g is shown in Table 4.1. Sample with hull contains higher content of Na, Ca and K with values (40.90, 76.10, 45.12) respectively than the samples containing hull with values (35.20 for Na, 60.30 for Ca, and 40.30 for K). The two samples also contain some amount of Mg, Zn, Fe, with a very trace amount of Cd (0.02ppm) for sample containing hull, but not detectable in sample without hull. Results from Table 4.3 shows that the bulk density for the sample without hull (0.435g/ml) is greater than the sample containing hull (0.385g/ml). Table 4.4. shows the result for the least gelation concentration (LGC) for sample without hull in different concentrations of ethylene glycol-water and ethanol-water mixtures. The LGC for sample without hull in 0% and 5% EG-H_20 12% w/v of the sample, while in 10% and 15% ethylene glycol-water, it is 14%. As the concentration of ethylene glycol-water mixture increases up to 15% - 25%, the Least Gelation Concentration (LGC) also increases to 16% w/v of the sample without hull. From this result, it shows that the Least Gelation Concentration (LGC) increases with increase in the concentration of ethylene glycol-water mixture. The Least Gelation Concentration (LGC) of the sample without hull in ethanol-water mixtures are 12%w/v, 14%w/v, 16%w/v and 18%w/v of the sample for 0%, 5%, 10% and 15% ethanol-water mixtures respectively. As the concentration of ethanol-water mixtures is increased from 15% to 25%, the Least Gelation Concentration (LGC) becomes stable and constant (18%w/v of sample without hull).

PROPERTY	SAMPLE WITHOUT HULL (A)	SAMPLE WITH HULL (B)
Bulk density	0.435	0.385

TABLE 4.3. BULK DENSITY

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EG-H_20 (%)	LGC(%w/vSAMPLE WITHOUT HULL)	LGC (%w/vSAMPLE WITH HULL)	ET – H_20 (%)	LGC (%w/vSAMPLE WITHOUT HULL)	LGC (%w/vSAMPLE WITH HULL)
0	12	12	0	12	12
5	12	12	5	14	14
10	14	12	10	16	16
15	14	12	15	18	16
20	16	16	20	18	18
25	16	16	25	18	18

TABLE 4.4: LEAST GELATION CONCENTRATION (LGC) FOR DEFATTED SAMPLE WITH HULL & WITHOUT HULL.
EG = Ethylene glycol; ET = Ethanol

Moreover, the Least Gelation Concentration (LGC) from Table 4.4 tends to be greater in ethanol-water mixtures than in ethylene glycol-water mixtures of the same concentration for sample containing hull. This may owe to the fact that there is more hydrophobic contribution of ethanol than that of ethylene glycol in water mixture. Results from this table also show that sample containing hull gelates quickly at a lower concentration in ethylene glycol-water mixtures. This result however still conform to the fact that the Least Gelation Concentration (LGC) increases as the concentration of the solvent mixture increases, as seen in ethylene glycol-water mixtures for the same sample.

Results from Table 4.5.1 and Table 4.5.2. show the solvent absorption capacity (SAC) as affected by the presence of the solvent mixtures. In Table 4.5.1, the %SAC for 0%EG and 25%EG are 200% and 260% respectively, while in 0% and 25% ethanol-water mixtures, the values are 200% and 320% respectively. These show that the higher the concentration of the solvent mixtures, the more the water or solvent absorbed by the sample. The Solvent Absorption Capacity (SAC) of the sample without hull in ethanol-water mixture is greater than ethylene glycol-water mixture despite the fact that both are alcohol. This may be as a result of the molecular structure of ethanol. The hexa-atomic ring of ethanol may strengthen the H-bonding interactions of ethanol with water and reduce the total energy of ethanol-water system [26]. Table 4.5.4. also shows the higher %Solvent Absorption Capacity (SAC) of the defatted sample with hull in ethanol-water than that of ethylene glycol-water. The variation between the %Solvent Absorption Capacity (SAC) of the two samples is that the sample with hull tends to absorb more water than the sample without hull. This owe to the fact that the hull which is purely fibre is made up of organic cellulose containing more OH-groups that could form H-bonding with water.

EG-H_20 (%)	MASS OF SAMPLE (g)	VOL. OF SOLVENT USED (ml)	VOL. OF SOLVENT ABSORBED (ml)	SOLVENT ABSORBED
0	0.5	5.0	1.0	200
5	0.5	5.0	1.0	200
10	0.5	5.0	1.1	220
15	0.5	5.0	1.2	240
20	0.5	5.0	1.3	260
25	0.5	5.0	1.3	260

TABLE 4.5.1 SOLVENT ABSORPTION CAPACITY (SAC) FOR DEFATTED SAMPLE A WITHOUT HULL IN EG-H_20.

ET-H_20 (%)	MASS OF SAMPLE (g)	VOL. OF SOLVENT USED (ml)	VOL. OF SOLVENT ABSORBED (ml)	SOLVENT ABSORBED (%)
0	0.5	5.0	1.0	200
5	0.5	5.0	1.0	200
10	0.5	5.0	1.1	220
15	0.5	5.0	1.2	240
20	0.5	5.0	1.4	280
25	0.5	5.0	1.6	320

TABLE 4.5.2. SOLVENT ABSORPTION CAPACITY (SAC) FOR DEFATTED SAMPLE A WITHOUT HULL IN ET-H_20.

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$$\% \text{ Weight of Solvent Absorbed} = \frac{\text{Volume of Solvent Absorbed}}{\text{Weight of Sample Used}} \; x \frac{100}{1}$$

EG-H_20 (%)	MASS OF SAMPLE (g)	VOL. OF SOLVENT USED (ml)	VOL. OF SOLVENT ABSORBED (ml)	SOLVENT ABSORBED (%)
0	0.5	5.0	1.2	240
5	0.5	5.0	1.2	240
10	0.5	5.0	1.3	260
15	0.5	5.0	1.4	280
20	0.5	5.0	1.4	280
25	0.5	5.0	1.5	300

TABLE 4.5.3.SOLVENT ABSORPTION CAPACITY (SAC) FOR DEFATTED SAMPLE B WITH HULL IN EG-H_20.

ET-H_20 (%)	MASS OF SAMPLE (g)	VOL. OF SOLVENT USED (ml)	VOL. OF SOLVENT ABSORBED (ml)	SOLVENT ABSORBED (%)
0	0.5	5.0	1.2	240
5	0.5	5.0	1.2	240
10	0.5	5.0	1.4	280
15	0.5	5.0	1.5	300
20	0.5	5.0	1.7	340
25	0.5	5.0	1.9	380

TABLE 4.5.4 SOLVENT ABSORPTION CAPACITY (SAC) FOR DEFATTED SAMPLE B WITH HULL IN ET-H_20.

The Oil Absorption Capacity (OAC in g/g) of sample without hull in ethylene glycol-water and ethanol-water mixtures as shown in Tables 4.6.0 and 4.6.1 depicts that the Oil Absorption Capacity (OAC) of the sample increases with increase in the concentration of the solvent mixture. The Oil Absorption Capacity (OAC) of the sample without hull in 0%, 5%, 10%, 15%, 20% and 25% ethylene glycol-water mixtures are 0.938g/g, 1.126g/g (for 5% and 10%), 1.501g/g (for 15% and 20%EG) and 1.876g/g respectively. In comparing the Oil Absorption Capacity (OAC) of the same sample in the two different solvent mixtures, the values obtained in ethylene glycol-water mixture is more than that obtained in ethanol-water mixture. Comparing the results from Tables (4.6.0 and 4.6.1) and Tables (4.6.3 and 4.6.4), sample containing hull tends to absorb much oil than the sample without hull. This may be traced to the presence of high amount of fibre in the sample containing hull.

The Foaming Capacity (FC) of sample without hull in ethylene glycol-water and ethanol-water mixtures is shown in Table 4.7.0 and Table 4.7.1 respectively. The Foaming Capacity (FC) of sample without hull in 0%EG was 9.52% which increases as the concentration of the ethylene glycol increases. This is also observed in ethanol-water mixtures of the same concentration, but the Foaming Capacity (FC) in ethanol-water mixture is greater than that in ethylene glycol-water mixtures. This owe to the less viscosity observed in ethanol, as opposed to high viscosity in ethylene glycol which prevents formation of bubbles within the molecule. Results from Table 4.7.2 and Table 4.7.3 also show that the Foaming Capacity (FC) of sample containing hull increases with increasing concentration of the solvent mixtures, but the Foaming Capacity (FC) is of greater value in sample containing hull than in sample without hull.

EG-H_20 (%)	MASS OF SAMPLE (g)	VOL. OF OIL USED (ml)	VOL. OF OIL ABSORBED (ml)	OAC (g/g)
0	0.5	3.0	0.5	0.938
5	0.5	3.0	0.6	1.126
10	0.5	3.0	0.6	1.126
15	0.5	3.0	0.8	1.501
20	0.5	3.0	0.8	1.501
25	0.5	3.0	1.0	1.876

TABLE 4.6.1 OIL ABSORPTION CAPACITY(OAC) OF DEFATTED SAMPLE A WITHOUT HULL IN EG-H_20 MIXTURE

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ET-H_20 (%)	MASS OF SAMPLE (g)	VOL. OF OIL USED (ml)	VOL. OF OIL ABSORBED (ml)	OAC (g/g)
0	0.5	3.0	0.5	0.9938
5	0.5	3.0	0.7	1.313
10	0.5	3.0	0.7	1.313
15	0.5	3.0	0.8	1.501
20	0.5	3.0	0.8	1.501
25	0.5	3.0	0.8	1.501

TABLE 4.6.2 OIL ABSORPTION CAPACITY (OAC) OF DEFATTED SAMPLE A WITHOUT HULL IN ET-H_20 MIXTURE

Mass of Oil Absorbed = Density of the Oil x Volume of the Oil Absorbed

$$\text{OAC (g/g)} = \frac{Mass\ of\ Oil\ Absorbed}{Mass\ of\ Sample}$$

EG-H_20 (%)	MASS OF SAMPLE (g)	VOL. OF OIL USED (ml)	VOL. OF OIL ABSORBED (ml)	OAC (g/g)
0	0.5	3.0	0.7	1.313
5	0.5	3.0	1.4	2.626
10	0.5	3.0	1.6	3.002
15	0.5	3.0	1.7	3.189
20	0.5	3.0	1.7	3.189
25	0.5	3.0	1.8	3.377

TABLE 4.6.3 OIL ABSORPTION CAPACITY (OAC) OF DEFATTED SAMPLE B WITH HULL IN EG-H_20 MIXTURE

ET-H_20 (%)	MASS OF SAMPLE (g)	VOL. OF OIL USED (ml)	VOL. OF OIL ABSORBED (ml)	OAC (g/g)
0	0.5	3.0	0.7	1.313
5	0.5	3.0	0.8	1.501
10	0.5	3.0	0.8	1.501
15	0.5	3.0	1.0	1.876
20	0.5	3.0	1.2	2.251
25	0.5	3.0	1.2	2.251

TABLE 4.6.4 OIL ABSORPTION CAPACITY (OAC) OF DEFATTED SAMPLE B WITH HULL IN ET-H_20 MIXTURE

EG-H_20 (%)	MASS OF SAMPLE (g)	VOLUME OF SOLVENT USED (ml)	VOLUME BEFORE WHIPPING (ml)	VOLUME AFTER WHIPPING (ml)	% FOAMING CAPACITY
0	0.4	20	21	23.00	9.52
5	0.4	20	21	23.20	10.48
10	0.4	20	21	23.60	12.38
15	0.4	20	21	23.80	13.33
20	0.4	20	21	24.20	15.24
25	0.4	20	21	24.20	15.24

TABLE 4.7.0. FOAMING CAPACITY (FC) OF DEFATTED SAMPLE A WITHOUT HULL IN EG-H_20 MIXTURE

ET-H_20 (%)	MASS OF SAMPLE (g)	VOLUME OF SOLVENT USED (ml)	VOLUME BEFORE WHIPPING (ml)	VOLUME AFTER WHIPPING (ml)	% FOAMING CAPACITY
0	0.4	20	21	23.00	9.52
5	0.4	20	21	23.80	13.33
10	0.4	20	21	24.20	15.24
15	0.4	20	21	24.40	16.19
20	0.4	20	21	24.50	16.67
25	0.4	20	21	24.80	18.10

TABLE 4.7.1. FOAMING CAPACITY (FC) OF DEFATTED SAMPLE A WITHOUT HULL IN ET-H_20 MIXTURE

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EG-H_20 (%)	MASS OF SAMPLE (g)	VOLUME OF SOLVENT USED (ml)	VOLUME BEFORE WHIPPING (ml)	VOLUME AFTER WHIPPING (ml)	% FOAMING CAPACITY
0	0.4	20	21	24.00	14.29
5	0.4	20	21	24.60	17.14
10	0.4	20	21	24.80	18.10
15	0.4	20	21	25.20	20.00
20	0.4	20	21	25.40	20.95
25	0.4	20	21	25.40	20.95

TABLE 4.7.2. FOAMING CAPACITY (FC) OF DEFATTED SAMPLE B WITH HULL IN EG-H_20 MIXTURE

ET-H_20 (%)	MASS OF SAMPLE (g)	VOLUME OF SOLVENT USED (ml)	VOLUME BEFORE WHIPPING (ml)	VOLUME AFTER WHIPPING (ml)	% FOAMING CAPACITY
0	0.4	20	21	24.00	14.29
5	0.4	20	21	24.60	17.14
10	0.4	20	21	25.00	19.05
15	0.4	20	21	25.60	21.90
20	0.4	20	21	25.80	22.86
25	0.4	20	21	26.00	23.81

TABLE 4.7.3 FOAMING CAPACITY (FC) OF DEFATTED SAMPLE B WITH HULL IN ET-H_20 MIXTURE

Upon study and constant examination and monitoring of the stability and behaviour of the foam in ethylene glycol-water and ethanol-water mixtures as shown in Table 4.7.4 to Table 4.7.7, virtually all the samples were found to have lost all their foams on or before 3.00hours after the appearance of the foams. Also samples were observed to foam more in ethanol than in ethylene glycol, but the foam disappears rapidly in ethanol than in ethylene glycol due to the low viscosity in ethanol. The foams disappear rapidly in sample containing hull than in sample without hull. This may be traced to the fact that sample without hull is denser than sample with hull. Also the hull (fibre) couldn't hold to a very long time the air bubbles formed on the top layer of the sample mixture.

TIME (HOURS)	0% (ml)	5% (ml)	10% (ml)	15% (ml)	20% (ml)	25% (ml)
0.00	23.00	23.20	23.60	23.80	24.20	24.20
0.25	22.20	22.80	23.00	22.40	23.00	23.20
0.50	21.80	22.40	22.20	22.20	22.20	22.40
1.00	21.20	21.60	21.20	21.40	21.40	21.80
3.00	21.00	21.00	21.00	21.20	21.20	21.20

TABLE 4.7.4. FOAMING STABILITY (FS) OF DEFATTED SAMPLE A WITHOUT HULL IN EG-H_20 MIXTURE

TIME (HOURS)	0% (ml)	5% (ml)	10% (ml)	15% (ml)	20% (ml)	25% (ml)
0.00	23.00	23.80	24.20	24.40	24.50	24.80
0.25	22.20	22.00	22.60	23.00	22.60	22.80
0.50	21.80	21.60	21.40	22.20	22.00	22.20
1.00	21.20	21.20	21.20	21.60	21.40	21.60
3.00	21.00	21.00	21.00	21.20	21.00	21.20

TABLE 4.7.5. FOAMING STABILITY (FS) OF DEFATTED SAMPLE A WITHOUT HULL IN ET-H_20 MIXTURE

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TIME (HOURS)	0% (ml)	5% (ml)	10% (ml)	15% (ml)	20% (ml)	25% (ml)
0.00	24.00	24.60	24.80	25.20	25.40	25.40
0.25	23.20	23.00	22.80	23.20	23.00	23.20
0.50	23.00	22.40	22.20	22.60	22.20	22.00
1.00	22.20	21.20	21.00	21.60	21.20	21.20
3.00	21.00	21.00	21.00	21.00	21.00	21.00

TABLE 4.7.6. FOAMING STABILITY (FS) OF DEFATTED SAMPLE B WITH HULL IN EG-H_20 MIXTURE

TIME (HOURS)	0% (ml)	5% (ml)	10% (ml)	15% (ml)	20% (ml)	25% (ml)
0.00	24.00	24.60	25.00	25.60	25.80	26.00
0.25	23.20	23.40	23.00	23.20	23.00	23.40
0.50	23.00	22.20	22.00	22.40	22.40	23.00
1.00	22.20	21.40	21.20	21.60	21.20	21.40
3.00	21.00	21.20	21.00	21.00	21.00	21.00

TABLE 4.7.7. FOAMING STABILITY (FS) OF DEFATTED SAMPLE B WITH HULL IN ET-H_20 MIXTURE

Table 4.8.0 and Table 4.8.1 shows the result for Emulsion Capacity (EC) of sample without hull in ethylene glycol-water and ethanol-water mixtures respectively. The Emulsion Capacity (EC) of this sample in ethylene glycol-water increases in 0%EG to 10%EG followed by gradual decrease in 15%EG to 25%EG. This is however slightly different in ethanol-water mixture as the Emulsion Capacity (EC) continually decreases from 0%ET to 25%ET. The results from Table 4.8.2 and 4.8.3 show that the Emulsion Capacity (EC) of sample containing hull is relatively lower than the sample without hull. This is as a result of the bulkiness and low fibre content of the sample without hull. Table 4.8.4 to Table 4.8.7 show results for Emulsion Stability (ES). The stability of the emulsion is greater in ethylene glycol than in Ethanol. This may be traced to the chemical structure of ethanol. Ethanol is more reactive and hygroscopic than ethylene glycol which is mostly inert. The %Oil Emulsified is higher in ethylene glycol than in ethanol as shown in Table 4.8.0 and 4.8.1. The %Oil Emulsified in 25%EG and 25%ET for sample without hull was 80.0% and 46.7% respectively. This can be traced to the fact that ethanol is more reactive and has higher affinity for water than oil. Ethylene glycol is mostly inert and has higher affinity for oil than water.

EG-H_20 (%)	MASS OF SAMPLE (g)	VOLUME OF OIL USED (ml)	OIL EMULSIFIED (g/g)	% OIL EMUSIFIED
0	0.5	3.0	4.69	83.30
5	0.5	3.0	4.88	86.70
10	0.5	3.0	4.88	86.70
15	0.5	3.0	4.69	83.30
20	0.5	3.0	4.69	83.30
25	0.5	3.0	4.50	80.00

TABLE 4.8.0. EMULSION CAPACITY (EC) OF DEFATTED SAMPLE A WITHOUT HULL IN EG-H_20 MIXTURE

ET-H_20 (%)	MASS OF SAMPLE (g)	VOLUME OF OIL USED (ml)	OIL EMULSIFIED (g/g)	% OIL EMUSIFIED
0	0.5	3.0	4.69	83.30
5	0.5	3.0	4.50	80.00
10	0.5	3.0	4.50	80.00
15	0.5	3.0	4.13	73.30
20	0.5	3.0	3.75	66.70
25	0.5	3.0	2.63	46.70

TABLE 4.8.1. EMULSION CAPACITY (EC) OF DEFATTED SAMPLE A WITHOUT HULL IN ET-H_20 MIXTURE

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EG-H_20 (%)	MASS OF SAMPLE (g)	VOLUME OF OIL USED (ml)	OIL EMULSIFIED (g/g)	% OIL EMUSIFIED
0	0.5	3.0	1.88	33.30
5	0.5	3.0	1.69	30.00
10	0.5	3.0	1.50	26.70
15	0.5	3.0	1.50	26.70
20	0.5	3.0	0.94	16.70
25	0.5	3.0	0.75	13.30

TABLE 4.8.2. EMULSION CAPACITY (EC) OF DEFATTED SAMPLE B WITH HULL IN EG-H_20 MIXTURE

ET-H_20 (%)	MASS OF SAMPLE (g)	VOLUME OF OIL USED (ml)	OIL EMULSIFIED PER (g/g)	% OIL EMUSIFIED
0	0.5	3.0	1.88	33.30
5	0.5	3.0	1.50	26.70
10	0.5	3.0	1.50	26.70
15	0.5	3.0	1.13	20.00
20	0.5	3.0	0.75	13.30
25	0.5	3.0	0.75	13.30

TABLE 4.8.3. EMULSION CAPACITY (EC) OF DEFATTED SAMPLE B WITH HULL IN ET-H_20 MIXTURE

$$\% \text{ Oil Emulsified } = \frac{\text{Volume of Oil Absorbed}}{\text{Initial Volume of Oil Used}} x \frac{100}{1}$$

EG-H_20 (%)	OIL EMULSIFIED (g/g)	VOLUME OF OIL SEPARATED (0.0HOUR) ml	VOLUME OF OIL SEPARATED (48HOURS) ml
0	4.69	3.0	3.0
5	4.88	2.3	2.3
10	4.88	2.5	2.5
15	4.69	2.8	2.8
20	4.69	3.2	3.2
25	4.50	3.2	3.2

TABLE 4.8.4. EMULSION STABILITY OF DEFATTED SAMPLE A WITHOUT HULL IN EG-H_20.

ET-H_20 (%)	OIL EMULSIFIED (g/g)	VOLUME OF OIL SEPARATED (0.0HOUR) ml	VOLUME OF OIL SEPARATED (48HOURS) ml
0	4.69	3.0	3.0
5	4.50	2.8	2.6
10	4.50	2.6	2.5
15	4.13	2.6	2.6
20	3.75	2.2	2.0
25	2.63	2.0	2.0

TABLE 4.8.5. EMULSION STABILITY OF DEFATTED SAMPLE A WITHOUT HULL IN ET-H_20.

EG-H_20 (%)	OIL EMULSIFIED (g/g)	VOLUME OF OIL SEPARATED (0.0HOUR) ml	VOLUME OF OIL SEPARATED (48HOURS) ml
0	1.88	2.6	2.6
5	1.69	2.8	2.8
10	1.50	3.0	3.0
15	1.50	3.6	3.6
20	0.94	3.6	3.6
25	0.75	3.6	3.6

TABLE 4.8.6. EMULSION STABILITY OF DEFATTED SAMPLE B WITH HULL IN EG-H_20.

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ET-H_20 (%)	OIL EMULSIFIED (g/g)	VOLUME OF OIL SEPARATED (0.0HOUR) ml	VOLUME OF OIL SEPARATED (48HOURS) ml
0	1.88	2.6	2.6
5	1.50	2.6	2.6
10	1.50	2.8	2.8
15	1.13	3.0	2.8
20	0.75	3.2	3.0
25	0.75	3.6	3.4

TABLE 4.8.7.EMULSION STABILITY OF DEFATTED SAMPLE B WITH HULL IN ET-H_20.

Figures 1 and 2 show the protein solubility curve for various ethylene glycol-water and ethanol-water mixtures respectively. This shows that the protein has different solubility at varied pH for different solvent mixtures with different maximum and minimum solubility. Minimum protein solubility in ethylene glycol-water was recorded between pH range of 2 and 4 for defatted sample without hull (Fig. 1 and 2). The protein solubility increases at either side of these pH values. Figures 3 and 4 also show protein solubility at different pH in different solvent concentrations, with minimum solubility at pH range between 3 and 6 for samples containing hull, while for sample without hull, the minimum solubility is at pH range between 3 and 5. These minimum pH (2 and 4 for sample without hull; and 3 and 6 for sample containing hull) will correspond to the isoelectric point of the two samples where there is maximum interaction between the ions of the protein molecules rather than interacting with the solvent. The highest protein solubility for the two defatted samples are generally attained at pH 9-11. This observation is due to intermolecular and intramolecular charge repulsion, leading to protein unfolding and producing more protein-solvent interactions [11],[12]. The hydrophobic groups within the proteins are exposed, hence, they tend to interact strongly with the hydrophobic group of ethanol than that of ethylene glycol when heated [26]. Comparison between figures 1 and 3, and figures 2 and 4 shows that the protein solubility is higher in samples without hull than in sample containing hull. Although there are several overlaps of protein solubility in different concentration of ethylene glycol-water and ethanol-water mixtures, the protein solubility still increases with increasing concentration of solvent mixtures.

pH	EG0	EG5	EG10	EG15	EG20	EG25
1	5.276243	8.563536	9.116022	8.577348	8.39779	7.734807
2	4.640884	10.1105	7.458564	7.071823	7.030387	6.79558
3	2.900552	6.754144	4.958564	5.138122	5.552486	5.939227
4	2.11326	8.701657	6.961326	7.30663	7.638122	7.18232
5	2.983425	7.265193	6.243094	5.966851	5.441989	4.972376
6	3.01105	7.348066	6.947514	7.417127	6.339779	6.767956
7	5.276243	5.883978	9.337017	8.39779	7.596685	7.320442
8	5.013812	11.90608	11.74033	11.32597	9.820442	9.558011
9	7.5	12.80387	13.34254	13.82597	11.67127	13.6326
10	6.505525	11.5884	15.74586	16.46409	14.6547	14.91713
11	6.892265	10.16575	13.95028	13.56354	13.27348	11.40884
12	6.671271	12.54144	12.77624	12.36188	12.34807	10.8011

TABLE 4.9.0. PROTEIN SOLUBILITY OF DEFATTED SAMPLE A WITHOUT HULL (mg/g) IN EG-H_20

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pH	ET0	ET5	ET10	ET15	ET20	ET25
1	5.276243	7.762431	8.411602	7.265193	6.491713	5.635359
2	4.640884	5.096685	6.533149	6.035912	6.91989	6.837017
3	2.900552	7.458564	5.179558	5.538674	5.372928	3.950276
4	2.11326	5.911602	4.972376	4.254144	3.121547	3.618785
5	2.983425	8.798343	4.792818	8.01105	2.348066	4.544199
6	3.01105	9.226519	7.707182	8.563536	5.441989	8.20442
7	5.276243	10.1105	11.10497	10.77348	6.395028	6.767956
8	5.013812	13.54972	8.453039	8.39779	6.712707	4.502762
9	7.5	15.27624	16.21547	12.43094	3.922652	8.632597
10	6.505525	13.92265	15.88398	14.00552	9.779006	9.779006
11	6.892265	12.87293	13.83978	12.72099	9.226519	8.756906
12	6.671271	15.46961	13.82597	13.28729	11.0221	11.40884

TABLE 4.9.1. PROTEIN SOLUBILITY OF DEFATTED SAMPLE A WITHOUT HULL (mg/g) IN ET-H_20

pH	EG0	EG5	EG10	EG15	EG20	EG25
1	5.179558	8.314917	7.651934	6.878453	6.395028	7.762431
2	4.046961	6.464088	6.878453	6.933702	7.334254	7.541436
3	2.265193	4.834254	5.234807	7.071823	5.566298	6.022099
4	2.969613	4.171271	2.582873	3.632597	3.977901	2.872928
5	2.803867	2.251381	2.762431	2.88674	3.370166	3.425414
6	2.831492	3.121547	2.955801	4.475138	5.290055	5.497238
7	4.046961	4.267956	4.61326	5.276243	7.472376	5.883978
8	8.176796	7.265193	5.911602	6.629834	8.135359	7.430939
9	6.464088	5.635359	5.428177	7.127072	7.845304	7.265193
10	9.143646	7.18232	6.79558	5.607735	7.720994	6.837017
11	8.162983	7.168508	7.748619	6.933702	6.892265	6.035912
12	5.745856	6.712707	7.348066	5.980663	5.31768	5.013812

TABLE 4.9.2. PROTEIN SOLUBILITY OF DEFATTED SAMPLE B WITH HULL (mg/g) IN EG-H_20

pH	ET0	ET5	ET10	ET15	ET20	ET25
1	5.179558	7.168508	7.071823	7.486188	7.403315	7.265193
2	4.046961	7.016575	6.588398	5.787293	6.339779	5.966851
3	2.265193	4.502762	2.900552	2.734807	4.68232	4.074586
4	2.969613	3.618785	2.69337	1.726519	3.259669	2.845304
5	2.803867	3.867403	3.245856	4.502762	1.947514	2.555249
6	2.831492	2.955801	3.770718	2.872928	2.679558	2.389503
7	4.046961	5.013812	6.436464	4.226519	3.729282	3.024862
8	8.176796	5.883978	3.301105	6.961326	5.19337	4.254144
9	6.464088	7.320442	8.466851	8.577348	8.936464	7.292818
10	9.143646	8.39779	7.997238	7.417127	8.549724	7.941989
11	8.162983	6.98895	8.674033	8.646409	8.480663	8.314917
12	5.745856	8.78453	8.71547	8.20442	9.185083	8.149171

TABLE 4.9.3. PROTEIN SOLUBILITY OF DEFATTED SAMPLE B WITH HULL (mg/g) IN ET-H_20

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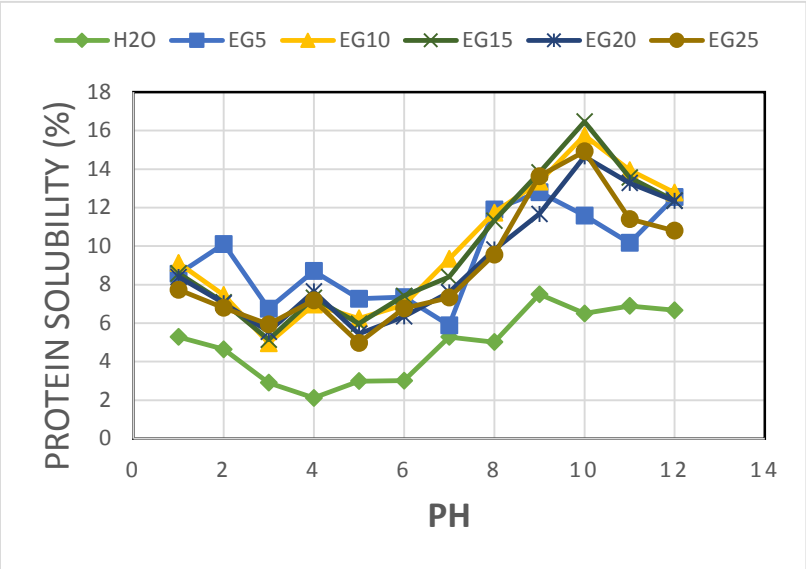

Figure 1.0. Protein Solubility of Defatted Sample A Without Hull (mg/g) In Ethylene Glycol-Water Mixture.

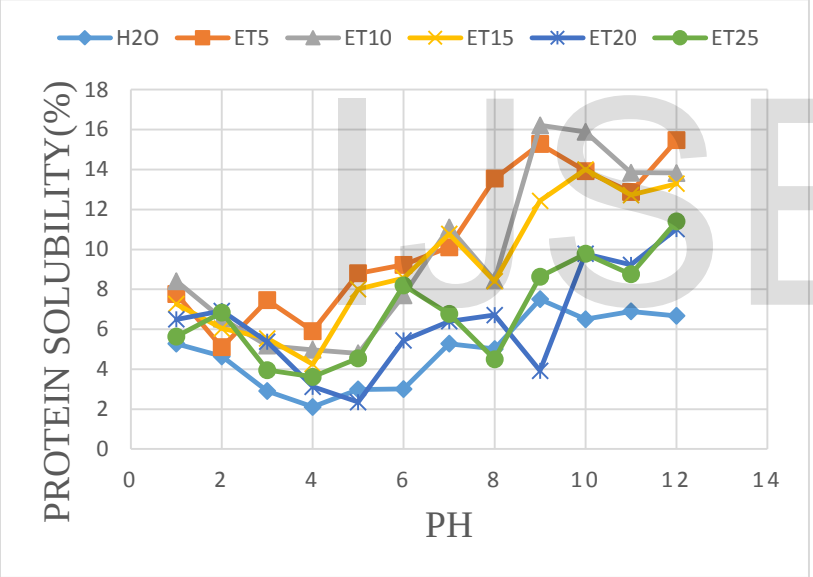

Figure 2.0. Protein Solubility of Defatted Sample A Without Hull (mg/g) in Ethanol-Water Mixture.

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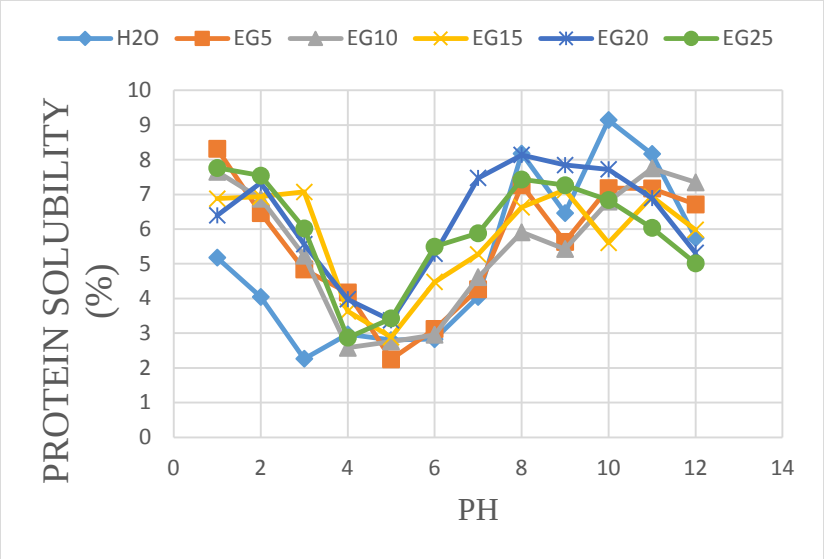

Figure 3.0 Protein Solubility of Defatted Sample B With Hull (mg/g) in Ethylene Glycol-Water Mixture.

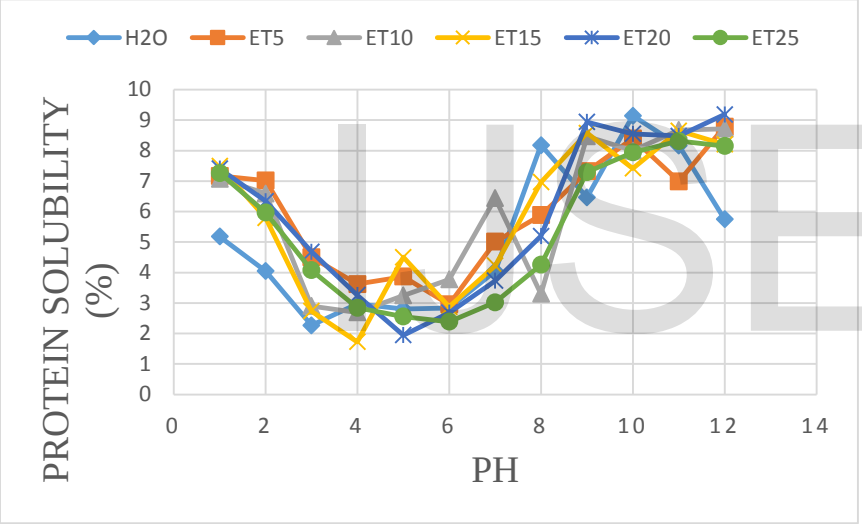

Figure 4.0 Protein Solubility of Defatted Sample B With Hull (mg/g) in Ethanol-Water Mixture.

4.0 CONCLUSION

This study reveals that the two samples of *Citrullus colocynthis L.* can be used as potential substitute for expensive fishmeal protein commonly used in animal feedstuffs, and as good protein supplements in dietary, and in the food and pharmaceutical industries. The results for mineral composition for sample containing hull and sample without hull show that *Citrullus colocynthis L.* is a good source of Na, Ca and K and must be recommended for patients which have deficiency of these essential minerals in their body. It can also be used as composite with other feedstuffs especially in animal feed formulation, where Ca, Na and K is moderately needed. Sample containing hull should be recommended in meals where high fibre content is required for adequate food digestibility. It should also be recommended for pregnant women and patients who require high intake of calcium, due to the higher percentage of calcium. The high protein content of the two defatted samples showed that they are good source of protein especially when needed in high quantity in diets. The raw undefatted samples contained high lipid content and are a good source of calories or energy than the carbohydrates. The functional properties suggest that the samples have high potential for use as functional ingredients in soups and frozen dessert.

The domestic and industrial importance of the functional properties of *Citrullus colocynthis L.* cannot be overemphasized. Therefore, more studies should be carried out on the effect of ethanol, ethylene glycol,

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polyhydric alcohols and other non-aqueous solvents on the functional properties of other classes of melon and proteins. The effect of salts concentrations and the effect of pH must be further carried out on the functional properties of melon (with and without hull). Moreover, variations in the physicochemical properties of the oil extracted from *Citrullus colocynthis L.* (sample containing hull and sample without hull) must be established to ascertain the consumers acceptability of the oil extracted from samples containing hull. Also efforts should be made to produce biofuels (via trans-esterification process) from the two samples and other classes of melon.

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