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Comparison of nutritional and functional properties of mung bean (*Vigna radiate*) and cowpea (*Vignaunguiculata*) protein isolates processed by isoelectric precipitation

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Abstract— **Dairy, wheat and soy are the most derive form of protein isolates and these are widely used in the food industry. The aim of this study was to extract and characterise legume protein isolates from low-fat legume seeds (Mung bean and cowpea). In this purpose, extracted protein isolates were compared with commercially available soy protein isolate to determine their potential usage in food applications. The isoelectric precipitation method was followed at pH of 4.5. Both protein isolate recovery(22.20±0.46 g / 100g) and protein yield (73.87±1.53%) were higher in mung bean protein isolate (MPI) as compared to cowpea protein isolate (CPI), i. e, 20.81±0.20 g / 100g and 68.89±0.66% respectively. The values for protein contents in legume protein isolates significantly differ ($p \leq 0.05$) from each other and higher amount (92.99±0.30%) in MPI followed by commercial SPI (90.98±0.32%) and CPI (89.00±0.53%) respectively. In the proximate composition of MPI, fat, fibre, ash and carbohydrate contents (on dry weight basis) were found to be 0.72±0.08%, 0.18±0.04%, 0.99±0.03% and 5.03%, respectively while CPI the same composition was found to be 0.81±0.05%, 0.22±0.01%, 1.15±0.11% and 8.72%. Results were compared with the commercially available soy protein isolate (SPI) with respect to the fat (0.43±0.02%), fibre (0.18±0.05%), ash (4.52±0.02%) and carbohydrate (3.89%) content in dry weight basis. Assessed functional properties of SPI exhibit high protein solubility, high water and oil absorption capacity than the MPI and CPI. Protein isolates from mung bean appeared to have the best gelling property.**

Index Terms— **Functional properties, Isoelectric precipitation, Legumes, Protein isolates**

I. INTRODUCTION

In Sri Lankan context, legume for human consumption invariably involves some rehydration and application of heat on traditional patterns, except peanuts. The least consumed legume as beans are soybeans. Nowadays, the major source of inexpensive proteins, especially designed for vegetarians, bodybuilders,also in various dairy, beverages industries and infant foods has become protein isolates, concentrates and textured plant protein. Soy isolates are much popular among legume protein isolates but researchers have made many efforts to develop protein isolates other grains than the soybean due to their allergy [1], [2]. Any alternative will be accepted, only if its functionality and price are competitive with soybean-derived products. Therefore, the present study was aimed to optimize the process and study the protein isolates from low-fat legume seeds (*Vignaradiate*and*Vignaunguiculata*) which are widely grown in Sri Lanka, while inexpensive and readily available in the market. Since no involvement of costly defatting process prior to extraction as the production of soybean isolates, mung bean and cowpea had a competitive advantage over other legume seeds. It includes aqueous extraction of soluble proteins from dehulled legume seed flour and separation of the insoluble residue, followed by precipitation of protein at mildly acidic conditions [3]. Functional properties related to the physical and chemical characteristics of the specific protein influence its behaviour in food system during processing, storage, cooking and consumption. The present work was designed to investigate the

preparation of protein isolates from low-fat legume seeds (mung bean and cowpea) by isoelectric precipitation and to analyse for their nutritional and functional properties. The investigated parameters and their respective results will be useful facts for formulating protein enriched products for target community.

II. MATERIALS AND METHOD

Materials: Commerciallyavailable varieties of mung bean and cowpea were purchased from the local market at Cargills Food City, Colombo and seeds were stored at 10°C until used. Bhun:jaLifesciences Soya Protein 90% Isolated (bhumi Pro) 200g pack, manufactured by Elcon Drugs and Formulation Ltd, F 59-60, India was used for comparison with mung bean and cowpea protein isolates. All other materials were obtained from regular suppliers and chemical reagents were of analytical grade (Sigma Aldrich Company Ltd).

Preparation of seed flour: Seed flour was prepared by dry milling process as described by Akaerue and Onwuka, 2010[4]. The dry cleaned whole legume seeds were initially dried at 60°C for 2h using a domestic air dryer. Then germination was carried out by spreading the whole seeds soaked in distilled water at 1:10 (w/v) ratio for 12 h at room temperature. After soaking they were rinsed twice with distilled water and hulls were removed manually. Dehulled legume seed were spread in a thin layer on a pan of domestic air dryer and dried at a fixed temperature of 65°C for 9h. They were stirred intermittently to maintain uniform heating and then cooled in a desiccator after drying. After cooling, seeds were dry milled using hammer mill(RETSCH S/S CROSS BEATER) to 0.5mm sieve size and further sifted with 45 mesh sieve (355µm) to obtained finer flour with similar particle size. Finally, flour was packaged in an airtight plastic bag for further analysis thereafter.

Preparation of mungbean and cowpea protein isolates by isoelectric precipitation method: Protein isolate from dehulledmung bean and dehulled cowpea flour were prepared using the method described by El-Adway, 2000 [5] with slight modification described by Makri et al., 2005 [6]. Known amount (nearest to 1mg) of dehulled legume seed flour (previously prepared) was dispersed in distilled water in 1:10 w/v (flour:water) ratio and flour suspension was adjusted to pH 9.0 using 1M NaOH at room temperature. The mixture was stirred at room temperature for 1h for allowing to hydration offlour. Then insoluble matrix was separated following centrifugation by refrigerated centrifuge (SIGMA 3-16K Centrifuge) at 4000rpm for 20 minutes and the supernatant was collected. In order to obtain increased yield, the extraction and centrifugation procedures were repeated once on the residue. For that, residue was collected and again dispersed in distilled water at 1:10 (flour:water) ratio at pH 11.0 and stirred for 30 minutes. Then centrifugation process was followed at 4000rpm for 20 minutes. The extracts were combined and the pH was adjusted to 4.5 with 1M HCl to precipitate protein. Then protein was isolated by centrifugation at 4000 rpm for 20 minutes followed by removal of the supernatant by decantation. White colour protein curd was washed with distilled water. As this way, washing and centrifugation processes were carried out thrice. The resulting protein curd was separated andit was placed in trays of domestic air dryer and dried for 4h ata low temperature (40°C). After drying it was ground into fine powder (500µm sieve) using centrifugal mill(FRITSCH). This protein isolate sample was packed in an Aluminium foil bag and store at cold condition (4°C) for analysis thereafter.

Compositional analysis:

Dehulled legume seed flours and protein isolates were analysed for their proximate composition and compared with the composition of commercial soy protein isolate by following their respective protocols as described in AOAC (2012);Moisture (Method No. 925.09B), crude protein with nitrogen conversion factor of 6.25 (Method No. 920.87), crude fat (Method No. 920.39C), crude fibre (Method No.962.09E) and total ash (Method No. 923.03)[7]. Total carbohydrate content was determinedby subtracting average values of crude protein, crude fat, crude fibre and total ash content of the sample from 100 by following the method of Sompong, 2011 [8].

Determination of isolate recovery: Recovery of prepared cowpea protein isolates were determined using the method described by Wang et al, 1999 [9]. According to that,it represents the weights of the protein isolates were attained after isoelectric precipitation per 100g weight of respective dehulled legume seed flour.

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Determination of protein yield: Protein yield of isolates were expressed by a formula, described by Wang et al, 1999 [9].

$$\text{Protein yield} = \frac{\text{Isolate recovery} \times \text{Isolate protein \%}}{\text{Dehulled legume seed flour protein \%}} \times 100$$

Functional Properties:

Protein Solubility; Protein solubility indices were determined in duplicates at various pH values ranging from 2 to 12 according to the method described inAOCS, 1974, method Ac 4-41[10] as modified byBetschart, 1974 [11]. Dispersions were prepared by dissolving 0.20 g of protein isolate with 20ml of distilled water. The pH of dispersions was adjusted by treating with either 1 M HCl or 1 M NaOH. The suspensions were continuously stirred for 30 minutes at room temperature and centrifuged using a SIGMA 3-16K refrigerated centrifuge at 4000×g for 30minutes. The resulting supernatants were filtered through Whatman(no. 1) filter paper and the protein content of 2ml of the clear supernatantswere estimated in triplicate by micro-Kjeldahl method as described in AOAC, 2012 with nitrogen conversion factor of 5.5 [12]. Then protein solubility of protein isolate was calculated as given below and plotted a graph between average protein solubility vs. pH values.

$$\text{Protein Solubility (\%)} = \frac{\text{Amount of nitrogen in the supernatant}}{\text{Total amount of nitrogen in 200 mg sample}} \times 100$$

Water Holding Capacity (WHC %);Water Holding Capacity was determined in triplicate according to the modified method of Sosulski et al, 1976 [13] and the AACC (2000c) method 56-30 [14]. Accurately 3.00g of protein isolate sample was measured in to the clean, dry and pre-weighed centrifuge tube and was mixed with 25ml of distilled water and kept for 30minutes. Then hydrated sample was centrifuge (SIGMA 3-16K) for 25minutes at 3000×g and the supernatant was removed by standing the centrifuge tube with its opening facing downwards at an angle of inclination for 25 minutes at room temperature. Then tube was re-weighed and WHC of protein isolate was calculated as follows;

$$\text{WAC (\%)} = \frac{\text{Weight of water absorbed by sample}}{\text{Weight of sample}} \times 100$$

Oil Absorption Capacity (OAC %); Oil Absorption Capacity of protein isolates was determined in triplicate as the method described by Sosulski et al, 1976 [13]. Accurately 0.50g of protein isolate sample was measured to the clean, dry and pre-weighed centrifuge tube. The sample was mixed with 6ml of corn oil and tube was stirred for 1minute toget the complete dispersion of sample in the oil. After 30 minutes holding time, sample was centrifuged for 25minutes at 3000×g and separated oil was removed with a pipette and hold the centrifuge tube downwards (opening side) at an angle of inclination for 25 minutes at room temperature. Then tube was re-weighed and OAC of protein isolate was calculated as follows;

$$\text{OAC (\%)} = \frac{\text{Weight of oil absorbed by sample}}{\text{Weight of sample}} \times 100$$

Least Gelling Concentration (LGC);Least Gelling Concentration of protein isolate was determined according to the method of Sathe&Salunkhe, 1981 [15].Exact amounts of protein isolate were weighed into test tubes containing 5ml of distilled water to make suspensions ranging in concentration from 2% to 20% (w/v).Then suspensions were stirred to get the complete dispersion and the tubes were sealed and heated at 100°C in a water bath for 60 minutes. After heating,tubes were cooled immediately under tap water and further cooled in a refrigerator at 4°C overnight. The tubes were kept in an invert position to determine if the suspensions had formed a gel. Observations made for the determination of gelling behaviour as follows. A firm gel wasconsidered to have occurred when on inverting the tube, the suspensions did not flow. At the invert position, a weak gel was in semi-solid formand flowed slightly. The least gelling concentration (LGC) is the concentration at which the sample did not slide along the test tube wall in the inverted position.All analysis was conducted in duplicate.

Data analysis: The data were statistically evaluated by one-way analysis of variance (ANOVA) by using Minitab 17 software and significant differences between means were determined by Tukey's multiple comparisons. One-way ANOVA was used for comparison between legume protein isolates. All test procedures were made at 5% significant level. Minitab 17 software was used to the graphical representation of data.

III. RESULTS AND DISCUSSION

Compositional analysis: In this context, protein isolates and dehulled legume seed flour used for isolations were analyzed for their proximate composition and results are presented in Table I.

Table I: Proximate composition of dehulled seed flour and protein isolates

	Mung bean		Cowpea		Soybean
Component (%)	Dehulled flour	Protein isolate	Dehulled flour	Protein isolate	Commercial soy protein isolate
Moisture	7.96 ±0.08	11.08 ±0.11[a]	6.81±0.22	11.11 ±0.05[a]	6.85±0.05[b]
Crude protein % dry basis	27.00 ±0.37	92.99 ±0.30[a]	25.65± 0.08	89.00 ± 0.53[c]	90.98± 0.32[b]
Crude fat % dry basis	1.13 ±0.01	0.72 ± 0.08[a]	1.79± 0.04	0.81± 0.05[a]	0.43± 0.02[a]
Crude fiber % dry basis	0.75 ±0.03	0.18 ± 0.04[a]	1.37± 0.02	0.22± 0.01[a]	0.18± 0.05[a]
Total ash % dry basis	3.59 ±0.01	0.99 ± 0.03[b]	2.99± 0.01	1.15± 0.11[b]	4.52± 0.02[a]
Carbohydrate* % dry basis	67.53	5.03	68.20	8.72	3.89

Results were expressed in Mean ± Standard deviation of triplicates and means with same superscript in a row are not significantly different ($p > 0.05$)

*Carbohydrate values are obtained by subtracting sum of average values of nutrients from 100% since standard deviations (SD) are not applicable here

Present findings regarding moisture content of protein isolates (MPI and CPI) were higher than respective dehulled legume seed flours from mung bean and cowpea. Moisture content of Both MPI and CPI were significantly ($p \leq 0.05$) higher than moisture content in commercial soy protein isolate (SPI).According to the Codex Standard 175, 1989 which has specified for compositional requirements applies to Vegetable Protein Products (VPP) prepared from soybeans (seeds of *Glycine max.L.*) by differentextraction methods, the moisture content of SPI should not exceed 10% (m/m) [16]. However, comparatively higher moisture content of protein isolates obtained from mung bean and cowpea inthe present study may be due to thepractical differences in drying method (oven drying at low temperature - 40°C).

The values for protein contents in legume protein isolates were significantly differ ($p \leq 0.05$) from each other and higher amount was obtained in mung protein isolate (92.99±0.30%) followed by commercial soy protein isolate (90.98±0.32%) and cowpea protein isolate (89.00±0.53%) respectively. Similar findings were observed by other scientist but with slight variations. In this regards, Akaerue and Onwuka, 2010 reported 87.56% protein content for mung protein isolate prepared by isoelectric method using dehulled mung bean flour with 28.3% protein content [4]. Likewise,91.3-91.3% protein value has been reported in Mwasaru, et al ,1999 as findings for cowpea isolate prepared by raw cowpea flour with 29.3% protein content [17]. This suggest, the variations in protein contents of different protein isolates could possibly be due to extent of soluble proteins present in initial legume seed flour used for isolation [18]. Results for protein content in commercial soy protein isolate lowered (90.98±0.32%) than that reported by Waggle and Kolar, 1979, i. e. 92% protein content [19]. However,

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Codex specifications has mentioned that it should be at least 90% or more protein contained in a isolate on a dry weight [16].

It is noticeable that the crude fat contents obtained by current study has higher values than previosly reported values. Fat content of SPI (0.43± 0.02%) is in agreement with the value (0.5%) reported by Waggle and Kolar, 1979[19]. Codex Std 175 (1989) mentioned that the fat content of soy protein isolates should be compatible with Good Manufacturing Practices [16]. Cowpea protein isolate has higher fat content than mung protein isolates but non-significant difference ($p > 0.05$) was observed among them. Reason in respect of the fat content of the processed raw material [20], which proves by findings of Mwasaru, 1999. As he reported, that fat content of cowpea protein isolate was 0.33-0.02% which made by isoelectric precipitation method using raw cowpea seed flour with 0.62% fat content [17]. These slight variations in fat content of legume seed flour may be due to varietal differences and environmental conditions [21]. Values are in accordance with previous literature and they described that isoelectric precipitation result in comparatively lower protein content and higher fat content than isolates obtained from ultrafiltration or membrane separation[1].

Highest fibre content (0.22±0.01%) was observed from CPI and fibre content of respect dehulled seed flour also somewhat higher (1.37±0.02%). These data closely associated with the work of Mwasaru, 1999 [17].Thefibre value of cowpea protein isolate is 1.78-1.79% and fibre content of raw seed flour had been used for isolation is 6.66%. The fibre content of MPI and commercial SPI were similar to each other. However presented results regarding fibre value of SPI comply with Codex specifications which describe that fibre content of protein isolates should not exceed 0.5% on dry weight basis while the limit is expressed as 5% for protein flour [16]. In general, fibre components mainly contain in the hull (Seed coat) of legume seed. During flour preparation, dehulling is carried out and it greatly effects to reduce fibre content in final product [22].

The highest total ash amount is observed in commercial SPI and the value is corroborated with the findings of Kolar, 1979, i.e 4.5% [19]. Also ash content of SPI was significantly ($p \leq 0.05$) higher than MPI and CPI. Previously, Mwasaru, 1999 reported that cowpea protein isolate has 2.02-1.97% amount of ash content and this values slightly varies from current result and ash content of its respective flour also higher (4.26%) than present finding regards dehulled cowpea flour (2.99±0.01%) [17]. In this case protein isolate obtained from whole cowpea seed caused to increase the ash content of a final product. Moreover, variations of ash content in protein isolates could be due to the amount of sodium chloride formation through the neutralisation process during preparation of protein isolates by isoelectric precipitation/ alkaline water extraction [23]. However, results in present study comply with the Codex specification, as described, that yield of ash on incineration should not be exceeded 8% on a dry weight basis [16].

In isoelectric precipitaion method, most of carbohydrates were separated by centrifugation technique followed after alkaline extraction.Carbohydrate content of CPI reported higher value (8.72%) and the lowest obtainedfrom commercial SPI (3.89%). The obtained results varied from those reported by Waggle and Kolar, 1979 [19] and Mwasaru, 1999 [17]. As they described carbohydrate content of soy protein isolate and cowpea protein isolate were reported as 0.3% and 2.97-4.92% respectively. Higher number of carbohydrate content in protein isolates may be owing to lower number of other compositional component andany errors in evaluations will be included in the final calculation Since the result is obtained by subtracting sum of average values of other nutrients from 100%.

Isolate recovery and protein yield of mung bean and cowpea protein isolates:

Table II: Protein isolates recovery and yield based on the protein content.

Legume protein isolate	Protein recovery (g / 100g of dehulled flour)	Protein yield (%protein)

Mung bean protein isolate	22.20±0.46[a]	73.87±1.53[a]
Cowpea protein isolate	20.81±0.20[b]	68.89±0.66[b]

Results were expressed in Mean ± Standard deviation of triplicates and means with same superscript in a column are not significantly different ($p > 0.05$)

Mean values for protein recovery and yield have been depicted in Table II. Maximum protein isolates recovery was revealed in MPI (22.20±0.46%) with higher protein content (92.99±0.30%) caused to gained higher protein yield (73.87±1.53%) based on the protein content of initial flour and protein isolate. Comparatively lower protein isolates recovery (20.81±0.20%) and lower protein yield (68.89±0.66%) were in CPI, similarly protein content was lower (89.00±0.53%) than MPI.

Functional properties: Size, shape, structure,net charge,amino acid squence and composition,molecular rigidity in response to external environment (salt concentration, pH, temperature), hydrophobicityand interaction with other constituentsof food are the factors that effect on the fuctional behaviour of proteins[24].

Protein solubility (%);The solubility of the isolates (MPI, CP and commercial SPI) were investigated at pH ranging from 2 to 12 to provide useful information towards effective utilisation of protein isolates in various food applications are presented in Table III and graphical representation in Figure I.

Table III. Protein solubility (%) of protein isolates from mung bean (MPI) and cowpea (CPI) in comparison to commercial soy protein isolate

Legume protein isolate	pH					
	2	4	6	8	10	12
MPI (%)	69	4	19	62	79	84
CPI (%)	57	4	8	28	65	82
Commercial SPI (%)	54	26	44	56	60	80

Results were expressed in Mean of duplicates

(MPI=Mung bean protein isolate; CPI=Cowpea protein isolate; SPI=Ssoy protein isolate)

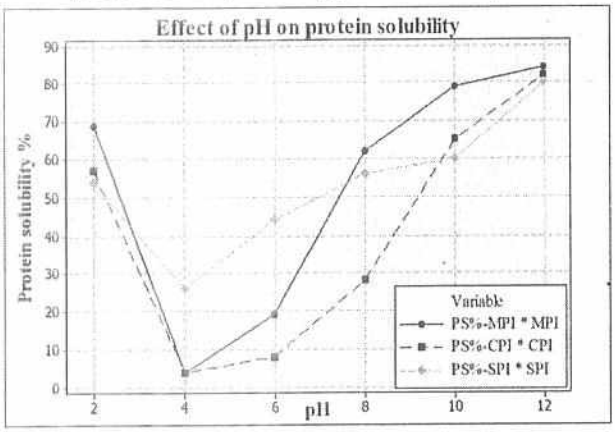

Figure I: Effect of pH on the protein solubility of protein isolates from mung bean (MPI) and cowpea (CPI) in comparison to commercial soy protein isolate (SPI). Mean (n=2)

In general, the effect of pH on protein solubility gives a U-shaped curve, where the higher solubility is shown to be on both sides of the isoelectric point (i. e. pH 4-6) and a lower solubility below the isoelectric point [25]. All three protein isolates have shown similar trends in solubility, which was maximal at both acidic (pH 2) and alkaline (pH 10-12) pH, but alkaline pH shows slightly higher solubility than acidic pH is in accordance with the finding of Fernandez, 1997 and Soottawat, 2013 [26], [27]. Protein has a positive or negative charge at pH values above and below the isoelectric point[28]. As expected, the solubility minimum around isoelectric point of the protein was in the pH range between 4 and 6. There was a marked increase in solubility above pH 6 in MPI while CPI and commercial SPI show gradual increment respect to pH. Present finding regards isoelectric point of legume proteins is in conformity with the findings of J. Boye, 2010 [1]; according to that the solubility of proteinmarkedly

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decreases near the isoelectric point which is usually ranged from pH 4 to pH 6 for most legume proteins. When compare the solubility behaviour between pH 4-6, both MPI and CPI exhibited very low values than value for SPI.Higher solubility of commercial soy protein isolate indicates it has good functionality and could have promising food application in beverage supplimentary food. However, KeShun, 1997 describes that,for optimum functional applications of vegetable proteins requires over 90% of protein solubility, such as soy protein isolate [29].

Water Holding Capacity (WHC %) and Oil Absorption Capacity (OAC%); Protein has both hydrophilic and hydrophobic properties thereby can interact with water and oil in food system [18]. The lower WHC of protein isolates is due to less availability of polar amino acids [30] and low OAC may due to the presence of large proportion of hydrophilic groups and polar amino acids on the surface of the protein molecules [31].

Table IV: WHC % and OAC % of protein isolates from mung bean, cowpea in comparison to commercial protein isolate from soybean.

Legume protein isolate	Water holding capacity (%)	Oil absorption capacity (%)
MPI	155.52 ± 2.21^{b}	87.56 ± 1.89^{a}
CPI	138.11 ± 1.32^{c}	78.58 ± 3.16^{b}
Commercial SPI	426.82 ± 0.92^{a}	90.5 ± 3.09^{a}

Results were expressed in Mean ± Standard deviation of triplicates andmeans with same superscript in a column are not significantly different ($p > 0.05$)

Table IV shows that mung and cowpea isolates in the current study compared unfavourably to those of a commercial soy isolate which gave a value of 426.82±0.92%. Present results are in agreement with the previous literature with slight variations. Butt and Batool, 2010 reported that Mung bean protein isolate and Cowpea protein isolate have WHC of 163 % and 138 % respectively [18]. The low water absorption capacities ofthe mung and cowpea isolates in the present study are in accordance with the work of Mwasaru et al, 1999. Because of the oven drying method used for dry the extracted moisten protein curd cause for formation of horny gelatinizedtexture during water absorption. This undesiarable texture have hindered the hydration ability of isolate[19]. Therefore materials having low WAC may render food products brittle and dry, especially during storage [1]. The results of water holding capacities of commercial soy protein isolate was similar to the values found by Meuser and Fuhrmeister, 2003, 460% [32] and Okezie and Bello, 1988, 4.10 g/g [33]. However, commercial soy protein isolate compared favourably to isolates from winged bean (5.00 g/g) [33] and Mucuna bean (6.00 g/g) [34]. The oil absorption capacities of mung bean (87.56±1.89%) and commercial soy (90.5±3.09%) protein isolates in the present study were not significantly differ ($p > 0.05$) and higher than that of a cowpea protein isolate (78.58±3.16%). Butt and Batool (2010) found that oil absorption capacity of mung bean and cowpea protein isolates were 113 % and 145 % respectively [18]. In the case of commercial soy protein isolates, Meuser and Fuhrmeister, 2003 observed 123% oil absorption capacity [32]. Other values reported for OAC of SPI in the literature fall between 254–261% [35], [36].

Least gelling concentration (LGC);

Gelation is an aggregation of denatured molecules. During heating food proteins have ability to develop a gel which determine their functionality in food processing. LGC is the qualitative parameter expresses the minimum protein concentration. Here, in inverted positiongel does not slide along the wall of testtube[37].The lower least gelation concentration value is the better gelling ability of protein because protein gels are aggregates of denatured molecules[38]. Table V summarises the gelling properties of the mung bean, cowpea and commercial soy protein isolates in present study. According to that no gels were formed at a concentration of 2% and 4% (w/v) irrespective of the isolate type or variety. At 6% concentration, the mung bean isolate formed a weak gel. A strong gel (√) was formed at 10% (LGC). The mung bean protein isolate, thus, had the best gelling properties while the cowpea protein isolate had lowest (LGC of 14%, w/v). Commercial soy protein isolate demonstrated intermediate gelling properties (LGC of 12%, w/v).

Table V: Gelling behaviour of mung bean and cowpea protein isolates with commercial soy protein isolate at different protein concentration. Mean (n=2)

Concentration % (w/v)	MPI	CPI	Commercial SPI
2	ΘΘ	ΘΘ	ΘΘ
4	ΘΘ	ΘΘ	ΘΘ
6	±Θ	ΘΘ	ΘΘ
8	±±	ΘΘ	ΘΘ
10	√√	±±	±√
12	√√	±±	√√
14	√√	√√	√√
16	√√	√√	√√
18	√√	√√	√√
20	√√	√√	√√
Least Gelling Concentration -LGC	10	14	12

Θ No gel; ± Weak gel; √Fine gel

These values are lower than those reported for mung bean (16% w/v) and cowpea (16% w/v) isolates by Butt and Batool, 2010 [18]. Circle and Smith, 1972 reported that resistant and firm gels are formed from SPI when their protein concentration at 16-17% [39] while Mwasaru, 1999 had presented the commercial soy isolate exhibited LGC of 12% [17].The week gel forming capacity is a result of low WAC [40]. This explains the cause for weak gelling property of MPI and CPI in current research.

IV. CONCLUSION

Conclusively, findings from this research provide additional economic potential with the use of such value-added in food applications using mung bean and cowpea seeds. From other studies, it has been suggested membrane separation/ ultrafiltration is an alternative to isoelectric precipitation resulting in improved protein recovery by reducing loss of acid soluble protein fraction and finally improved their physico-functional properties in food applications.

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