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NUTRITIONAL, FUNCTIONAL AND ANTI-OXIDANT PROPERTIES OF SELECTED ORGANIC AND CONVENTIONALLY GROWN LEGUMES

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ABSTRACT

The study aimed at determining nutritional, functional and antioxidant properties of organic and conventionally (non-organic) grown horse gram, moth beans and Red kidney beans. Samples were procured from certified sources, converted to flours and analyzed using standard techniques. Nutrient analysis revealed that legumes had a high protein (19.8-22.5%) and low fat (0.75-1.45%) content. Dietary fiber content was more in horse gram and kidney bean (22.28-23.79%) and less in moth bean (12.08-13.52%). There were significant differences in nutritional composition of organic and conventional legumes, though no specific trend was observed and it varied depending upon the legume. Organic legume showed significantly lower phytic acid content. Functional properties showed that organic legumes had lower water absorption capacity and higher emulsion activity. Horse gram had high phenolic constituents. Legumes exhibited high antioxidant activity with minor differences between legumes. In conclusion, organic and non-organic legumes showed some differences in nutritional and functional properties, however, no trend was observed.

KEYWORDS

Nutritional composition, Digestible protein and starch, Bioaccessible minerals, Emulsion capacity, Foaming properties and Anti-oxidant activity.

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INTRODUCTION

The increase in use of pesticides to increase the yield and resistance of crop towards pests and infestation has resulted in a shift of consumer's choices towards purchase of organic foods. Present day consumers are strongly concerned about potential hazards caused by pesticide residue in food[1]. Organic foods are produced according to certain production standards, implying they are grown without the use of pesticides and artificial fertilizers, free from contamination by human or industrial wastes and processed without ionizing radiation or food additives. Researchers have also found that organic farming has potential of producing healthy foods with higher nutritional quality and decreases harm caused by unhealthy farming practices[2]. Some authors have found that organic crops contain more minerals such as iron, magnesium and phosphorus and vitamins, particularly vitamin C in most of the studies than non-organic crops which have shown higher nitrate content. Higher levels of nitrate consumption are associated with health problems such as cancer. There are large numbers of factors that can affect the nitrate content of crops, such as excessive applications or improper timing of fertilizer or compost which can lead to excessive nitrate level in plants[3]. Winter and Davis[4] report that organic agriculture could result in higher polyphenol quality in foods as the absence of synthetic pesticides could result in higher exposure of the plant to stressful situations leading to an enhancement of natural defense substances such as phenolic compounds. During present times, the number of people suffering from lifestyle diseases such as diabetes, obesity, allergies, cancer, etc. is increasing worldwide due to increasing environmental pollution, unhealthy eating habits and improper lifestyle. Additionally, the nutritional value of food is continuously deteriorating, emphasizing the consumption of healthy diets comprising of high quality foods. Most of the studies show organic foods having higher quality nutrients compared to non-organic ones which indicate that organic produce may significantly contribute to the promotion of health.

From the reviewed literature, it can be said that a limited number of studies have compared the nutrient composition of organically and conventionally grown legumes and very few compositional differences have been reported. Thus, the present study was undertaken to evaluate the nutritional, functional and antioxidant properties of organically grown legumes in comparison with conventionally grown counterparts. The choice to focus on legumes was motivated first by their importance as a source of protein, minerals, dietary fiber and various beneficial phytochemicals and secondly by the growing importance of organic food market with a wide availability of legumes.

METHODOLOGY

Material

Organic certified legumes, namely, horse gram (*Macrotylom auniflorum*), moth beans (*Vigna aconitifolia*) and Red kidney beans (*Phaseolus vulgaris*) (certified by India organic, USDA and European organic) were procured from a certified organic shop and its counterpart of non-organic legumes were procured from local market in Mysore, India. After cleaning and drying, grains were milled into flours in plate mill so as to pass through 60-mesh sieve. The flours were stored in airtight plastic bags and kept in dark, at 4°C, until further analysis. All the chemicals used in the study were of analytical grade. Gallic acid, TROLOX, catechin, Folin-Ciocalteu reagent, iron, calcium, and zinc standards for Atomic absorption spectrophotometry were purchased form Sigma-Aldrich Co., (St. Louis, MO, USA).

Nutrient composition

Nutrient composition of legumes flour for moisture, protein, fat and ash content were carried out by following standard methods of AOAC[5]. In brief, the methods were estimation of moisture by oven drying and weighing, protein by Kjeldahl distillation and conversion of nitrogen to protein, and fat by Soxhlet distillation apparatus using solvent. Total dietary fibre (TDF) was determined by rapid enzymatic assay[6]. Mineral content i.e. iron, zinc and calcium in legume flours were analyzed by charring known quantity of sample flour followed by incineration in muffle furnace at 550°C for 6 hrs. The ash was dissolved in 7 ml concentrated HCl (Sp.Gr.1.18) and evaporated to dryness on water bath, 4 ml HCl was again added along with few drops of triple distilled water and boiled for few min. Later, the solution was filtered through ash less filter paper and made-up to known volume. The concentration of minerals in ash solution was measured by atomic absorption spectrometry (Shimadzu AAF-6701). Phosphorous content of legume flours was analyzed by the method of Taussky and Shorr[7].

Phytic acid and Tannin Contents

Phytic acid was extracted from legume flour and determined according to the precipitate analysis method of Thompson and Erdman[8]. The conversion factor 3.55 for phosphorous to phytic acid was used[9]. Condensed tannins were determined according to the vanillin-HCl procedure and results were expressed in milligrams of (+)-catechin equivalents per gram[10].

***In vitro* availability of nutrients**

***In vitro* Protein digestibility**

In vitro digestibility of protein in legume flours was determined by method of Akeson and Stahman[11]. In brief, a known amount of sample (containing 100mg protein) was incubated sequentially with pepsin and pancreatin with appropriate pH adjustments as required, the undigested protein was separated with trichloroacetic acid precipitation, and nitrogen was estimated in supernatent by Kjeldahl's method. *In vitro* digestibility was expressed as the percentage of the total protein solubilized after enzyme hydrolysis.

***In vitro* starch digestibility**

In vitro starch digestibility was determined following the procedure of Ngo Som *et al*,[12]. Defatted legume flour (100 mg) was mixed with 10 ml of water containing 0.5 ml of term amyl and heated in a boiling water bath for 15 min. To the contents, phosphate buffer (15 ml, pH 6.8) containing 15 mg of pancreatin was added and incubated at 37 °C for 2 h. The pH of the reactants was then lowered to 4.5 using dilute acetic acid, and acetate buffer (0.05M, 15 ml, pH 4.5) containing 15 mg of amyloglucosidase was added and incubated for 2 h at 55 °C. The glucose released was estimated by using the dinitrosalicylic acid reagent.

Mineral bioaccessibility

Mineral bioaccessibility was analyzed by *in vitro* method of dialysis by simulating gastrointestinal digestion[13]. To 20 g of legume flour, 70 ml of water was added and pH was adjusted to 2.0 using 6 M HCl, incubated with 3 ml pepsin (16 g/100 ml of 0.1 M HCl) at 37°C for 2 h. Titratable acidity was measured in an aliquot of the gastric digest with 5 ml pancreatin-bile extract mixture (400 mg pancreatin and 2.5 g bile extract dissolved in 100 ml of 0.1 M sodium bicarbonate) by adjusting the pH to 7.5 using 0.2 M sodium hydroxide. The volume of sodium hydroxide required to attain pH 7.5 was noted and the equivalent moles of sodium bicarbonate were computed. Intestinal digestion was simulated by placing the dialysis tubing containing 25 ml of sodium bicarbonate (quantity derived from titrable acidity) solution in an aliquot of gastric digest. Incubation was continued for 30 min and 5 ml of pancreatin-bile extract was added and continued incubation for 2 h. Iron, zinc and calcium present in the dialysate represents the minerals that are in the absorbable form. The quantity of the dialyzable minerals was estimated using atomic absorption spectroscopy. Percent bioaccessibility of the minerals was computed by comparing the dialyzable mineral with the total mineral present in the flour.

Functional properties

The organic and non-organic legume flours samples were dried at 40˚C for 24hrs to attain equilibrium moisture before determining functional properties. Water absorption capacity (WAC) of the legume flour were determined following the procedure of Elhardallou and Walker[14] and reported as the g of water absorbed/100g of the dry flour. For measuring water solubility index, the method described by Anderson, Conway, Pfeifer and Griffin[15] was followed by calculating the weight ratio of dissolved solids in the supernatant and dry sample. Oil absorption capacity (OAC) were estimated by centrifuging a known quantity of legume flour with oil following the procedure of Sosulski *et al*,[16] and reported as the g of oil absorbed/100g of the dry flour. Emulsion activity and emulsion stability were evaluated by using the method of Yasumatsu *et al,*[17]. Foam capacity and foam stability were determined according to the method of Coffmann and Garcia[18]. The volume of the foam was recorded as foam capacity and monitored at regular intervals for 15 - 30 min to evaluate stability. The flour bulk density was estimated using the method of Okezie and Bello[19]. The soluble nitrogen content of legume flours was determined at different pH from 2-11 by adjusting the pH with 0.1M HCl and 0.1M NaOH. The amount of protein in the supernatant was determined by using Barford's reagent (Sigma-Aldrich chemical company, St. Louis, USA). The soluble protein was expressed in mg/g of flour sample.

Determination of Total Phenolics, Flavonoids and Antioxidant activity

The legume flour samples were extracted in 1% HCl-methanol at 50 °C for 3 h. The extraction was repeated three times, the extracts pooled and analyzed for phenolic and antioxidant activity. Total phenolic compounds were determined according to the Folin-Ciocalteu procedure as described by Matthaus[20] by measuring the absorbance at 760 nm, and results expressed as mg gallic acid equivalents/g of legume flour. Total flavonoid content was determined according to the method described by Jia *et al*,[21] by reading the absorbance at 510 nm. The results were expressed as mg catechin equivalents/g of flour. The antioxidant activity of legume flours was analyzed using following assays.

Free Radical Scavenging Activity (DPPH assay)

Free radical scavenging capacities of the legume flour were determined by reaction with the 2, 2´ - diphenyl-1-picrylhydrazyl (DPPH) radical, according to the method adapted from Brand-Williams *et al*,[22]. Briefly, an aliquot of samples was mixed with 2.7 ml of a methanol solution of DPPH (500 μM). The mixture was shaken vigorously and left to stand at room temperature for 60 min in the dark. The absorbance was measured spectro-photometrically at 517 nm. Decreasing the absorbance of the DPPH solution indicates an increase in DPPH radical scavenging activity.

Metal Chelating Activity

The chelating of ferrous ions by the phenolic extracts of legume flour was estimated by the method of Dinis *et al*,[23]. Briefly, the extract was added to 0.05 ml of 2 mM $FeCl_2$. The reaction was initiated by the adding 0.2 ml of 5 m Mferrozine; the mixture was vortexed and allowed to stand at room temperature for 10 min. Absorbance of the solution was then measured spectro-photometrically at 562 nm.

Ferric reducing antioxidant power (FRAP)

FRAP assay of phenolic extracts of legume flour was performed according to a modified protocol developed by Benzie and Strain[24]. A calibration curve was prepared, using an aqueous solution of ferrous sulphate. FRAP values were expressed on a dry weight basis as micromoles of ferrous equivalent per 100g of legume flour (µmol Fe^{2+}/100g).

Statistical analysis

Results were expressed as mean standard deviation (SD) of three measurements. The significance difference was tested by using Student’s t-test at $p<0.05$. All statistical analyses were performed using SPSS 16.0 (SPSS[25]).

RESULTS AND DISCUSSION

Nutrient composition

The nutritional composition of horse gram, moth bean and red kidney beans from both organic and conventional (non-organic) sources are presented in Table No.1. Organic and non-organic horse gram and red kidney bean had similar moisture content of around 10% and relatively lesser was seen in moth beans (7%). Protein contents of organic legume flour were significantly different from non-organic source. Conventionally grown horse gram and moth bean showed higher protein content than organic samples ranging from 21.5-22.5g/100g. In comparison, red kidney bean had a lower content and showed a different trend too. It is said that high fertilizer application increases protein concentration and water content with rapid growth by simply swelling to increase the yield of crop, however, it eventually decreases the nutritional quality of protein[26,27]. The quantity of nitrogen fertilizer used influences the quality of protein by decreasing the proportion of essential amino acid[28]. The fat content of all legumes were low (0.75-1.45%) with significant difference observed only for horse gram. Horse gram and red kidney bean had higher dietary fibre content ranging from 22.28 -23.79g/100g with higher value in organic flour when compared with moth bean (12.08 - 13.52g/100g) which had higher content in conventional flour. The proportion of IDF was very high and it followed a similar trend. Soluble dietary fibre showed differences in organic and conventional legumes, though did not follow any trend. Since the analyzed legume had lesser fat content of around 1% and higher dietary fibre content, inclusion of these whole legumes possibly will lower the risk of obesity, heart disease and diabetes.

Ash content in analyzed legumes ranged from 3 - 4 %, slightly higher values were reported in organic legumes than conventional ones, which indicate a higher mineral content. Iron, calcium and phosphorous contents of legume flours from organic and conventional sources differed significantly from each other. Horse gram and moth bean had similar iron content ranging from 7.22-7.44 mg/100g, whereas moth bean had a lesser amount. Calcium and phosphorous content of legumes varied from 136 - 249 mg/100g and 310 - 458 mg/100g respectively. Both sources of horse gram and moth bean did not have significant difference in zinc content and a range of 2.56 - 3.61 mg/100g was reported in the analyzed legumes. Such variations in mineral contents of organic and conventionally grown grains have been reported previously. Ryan *et al,*[29] studied grain mineral concentration under organic and non-organic management and found greatly increased yield of non-organic grains with minor variation in N, K, Mg, Ca, S and Fe concentration. They also reported that organic grain had higher Zn and Cu, but lower Mn and P than non-organic grains.

Anti-nutrient content

The phytic acid content of organic legumes flour was significantly lower than conventional legume flour (Table No.2). The phytic acid content of red kidney beans was observed to be highest among the analyzed legumes. Similar values have been reported in literature[30]. The tannin content of legume flours are as follows: horse gram > red kidney bean > moth bean. The differences between organic and non-organic legumes were statistically significant ($p < 0.05$) with no clear trend.

***In vitro* availability of nutrients**

The *in vitro* starch and protein digestibility and mineral bioaccessibility of both organic and non-organic legume flour are given in Table No.3. Organically grown legumes exhibited significantly higher starch digestibility. The *in vitro* protein digestibility was higher in non-organic horse gram and organic moth bean and kidney beans with significant differences. Though when considered as percent digestibility, all organic samples exhibited a higher value. The *in vitro* protein digestibility values of red kidney beans from both origins are similar to the results reported for *Beshbesh* variety of red kidney beans[31]. The superior *in vitro* protein digestibility of organic legumes may be attributed by better quality of protein in organic legumes. And another reason for better digestibility could be the lower anti-nutrient content in organic legumes compared to non-organic once.

Bioaccessible iron did not follow any trend and only 3.32-5.06% of total iron was bioaccessible. Non-organic moth bean and organic kidney bean showed higher bioaccessibility. It may be noted that iron absorption in general from whole legumes is low because of presence of many anti-nutritional factors and dietary fiber. Legumes had a high content of phytic acid and dietary fiber, thereby lowering the iron bioaccessibility. Zinc followed a similar trend, though percent absorption of zinc was much higher than iron, the range being 22.03-24.15% for horse gram, 10.54-14.92% for moth bean and 14.72-18.51% for kidney bean. Calcium absorption was similar for organic and non-organic horse gram, and significantly higher for non-organic moth bean and organic kidney bean. Calcium bioaccessibility was also low on account of anti-nutritional factors as observed for other minerals.

Functional properties

Table No.4 presents the functional properties of legume flour from organic and non-organic sources. The WAC of horse gram and red kidney beans showed no significant differences between organic and conventional legumes with values of 142.6 - 150.1g/100g and 132.8 - 139.6g/100g respectively. This evidently shows no change in amino acid and carbohydrate content between organically and conventionally grown legumes. The WAC values of horse gram and red kidney beans can be compared with studies of Sreerama *et al,*[30] and Shuang-kui *et al,*[32] for dehulled horse gram (148.1 g/100g) and red kidney beans (1.67g/g) respectively. Highest water solubility index value and oil absorption capacity of 20% and 95% respectively was observed in red kidney beans. Horse gram and moth bean absorbed similar amount of fat ranging from 81 - 85 % with no significant difference between organic and non-organic grown legumes. Among the functional property of legume flours, emulsion stability is an important factor for the formation of fat and water phase stability required for baked food products. Organically grown legumes showed significantly higher emulsion activity and emulsion stability than the non-organically grown ones. Emulsion activity was highest in moth bean (20 - 35 %) with least stability and surprisingly red kidney beans having least emulsion activity showed highest emulsion stability (64 - 76 %). Bulk density of legume flour was in similar range with slightly lower value in red kidney bean and organic flours were significantly different from conventional flours. Non-organic moth bean and red kidney beans had higher bulk density except horse gram where organic flour showed higher values.

Foaming properties such as foaming capacity and stability of legume flours depicts the flours leavening property, which is an important criteria for baked products. Foam capacity in organic horse gram flour showed a little higher value than non-organic legumes and other two showed no significant difference (Table No.5). The foaming stability of legume flour was recorded at time interval of 15-30min over a period of 2 h. First 15 min showed high foam stability of legume flour, later it reduced to half at 120min when compared with value at initial time. The foaming stability of legume flours of both sources at 90 and 120 min differed significantly. Red kidney beans had greater capacity of foam formation (68%) with poor retention, whereas horse gram showed relatively high foam stability (33-35%).

The protein solubility of the flour was investigated at pH values ranging from 2 to 10. The differences in protein solubility, as affected by pH are shown in Figure No.1. The protein solubility of legume flours i.e. horse gram, moth bean and red kidney bean was least at pH 4.0 and highest at pH 2.0 and 10.0.

Total phenol content and antioxidant activity

The phenol content and antioxidant activity of organic and conventionally grown legume flours were determined and the results are shown in Table No.6.

Distinctive variations were observed in total phenol content (TPC) and total flavonoid content (TFC) in both sources of legumes. Total phenol content of legume flour was similar in organic and non-organic legumes, exhibiting higher values in horse gram followed by moth bean and red kidney beans. Zuchowski *et al*,[33] investigated phenolic acid concentration in organically and conventionally cultivated wheat varieties and reported that organically produced wheat variety had significantly higher concentration of total phenolic acid content than non-organic wheat with minor differences, whereas study by Dimberg *et al*,[34] with organic and non-organic oats did not show any differences in phenolic compound concentration. The total flavonoid content was higher in organic horse gram (1.64 mg/g) and non-organic red kidney bean (0.75 mg/g) and similar in case of moth bean (0.08 mg/g).

The DPPH radical scavenging activity of horse gram ranged from 74.7 - 75.2 µmol TROLOX/g followed by moth bean with 62.2 - 64.4 µmol TROLOX/g and 57.6 - 58.7 µmol TROLOX/g in red kidney beans with no significant difference between different agricultural practices. FRAP activity of moth bean extracts showed highest of 0.22 – 0.25 mM $FeSo_4$/g and lowest in red kidney bean (0.09 mM $FeSo_4$/g) and the activity was similar in both organic and non-organic legumes. In metal chelating assay, phenolic extract of horse gram showed highest of 2.27 - 2.34 µmol EDTA/g and moth bean and red kidney beans had similar range of 1.60 - 1.98 µmol EDTA/g. Metal chelating activity of organic moth bean and non-organic red kidney beans showed higher values than its counterpart. Overall, horse gram exhibited higher antioxidant activity among the legume flours analyzed.

Table No.1: Nutritional composition of organic and non-organic legume flours

S.No	Constituent (per 100g)	Horse Gram		Moth Bean		Red kidney beans	
		Organic	Non-organic	Organic	Non-organic	Organic	Non-organic
1	Moisture (g)	9.23 ± 0.18	10.22 ± 0.26*	7.62 ± 0.15	7.85 ± 0.17^{ns}	10.63 ± 0.23	10.64 ± 0.10^{ns}
2	Protein (g)	20.0 ± 0.4	21.5 ± 0.0*	21.9 ± 0.2	22.5 ± 0.0*	20.3 ± 0.0	19.8 ± 0.0*
3	Fat(g)	0.77 ± 0.01	0.85 ± 0.00*	0.80 ± 0.09	0.75 ±0.05^{ns}	1.42 ± 0.06	1.45 ± 0.05^{ns}
4	CHO[a] (g)	70	67.4	69.7	68.9	67.7	68.1
Dietary Fibre (g)	Total	23.79 ± 0.4	22.39 ± 0.2*	12.08 ± 0.3	13.52 ± 0.5*	23.21 ± 0.4	22.28 ± 0.5*
	Insoluble	23.09 ± 0.3	21.12 ± 0.1*	9.10 ± 0.2	11.66 ± 0.5*	19.91 ± 0.3	18.45 ± 0.4*
	Soluble	0.7 ± 0.0	1.3 ± 0.0*	3.0 ± 0.0	1.9 ± 0.0*	3.3 ±0.0	3.8 ± 0.0*
5	Mineral (g)	3.52 ±0.03	3.08 ± 0.03*	3.60 ± 0.08	3.53 ± 0.10^{ns}	4.09 ± 0.07	3.64 ± 0.03*
6	Iron (mg)	7.36 ±0.09	7.44 ± 0.47*	7.22 ± 0.16	7.36 ± 0.13*	8.78 ± 0.18	9.92 ± 0.35*
7	Zinc (mg)	2.78 ± 0.08	2.56 ± 0.07^{ns}	3.56 ± 0.36	2.86 ± 0.04^{ns}	3.25 ± 0.03	3.61 ± 0.08*
8	Calcium (mg)	196±4.74	249± 0.88*	172± 0.21	162±1.61*	136±0.54	152± 3.46*
9	Phosphorous (mg)	446±0.96	310 ±1.36*	355 ±1.67	262 ±2.36*	435 ± 1.36	458 ± 2.36*

Means with superscript '*' are statistically significant at $p < 0.05$, ns - not significant. [a]: Carbohydrates by difference.

Table No.2: Phytic acid and tannin content in organic and non-organic legumes flours

S.No	Constituent	Horse Gram		Moth Bean		Red kidney beans	
		Organic	Non-organic	Organic	Non-organic	Organic	Non-organic
1	Phytic acid (mg/g)	9.0 ± 0.01	9.6 ± 0.02*	5.9 ± 0.00	6.4 ± 0.02*	9.4 ± 0.02	10.8 ± 0.04*
2	Tannins (mg/g)	3.10 ±0.06	2.65±0.06*	0.91±0.06	1.10 ±0.09*	1.44±0.03	1.34±0.06*

Means with superscript '*' are statistically significant at $p < 0.05$, ns - not significant.

Table No.3: *In vitro* digestible and bioaccessible nutrients in organic and non-organic legume flours

S.No	Constituent (per 100g)	Horse Gram		Moth Bean		Red kidney beans	
		Organic	Non-organic	Organic	Non-organic	Organic	Non-organic
1	Starch (g)	46.3 ± 0.6	45.8 ± 2.5*	50.1 ± 0.5	49.1 ± 1.3*	45.9 ± 1.3	43.9 ± 0.7*
2	Protein (g)	9.06 ± 0.09 (45.3)	9.38 ± 0.88* (43.6)	11.88 ± 1.80 (54.2)	11.08 ± 0.02* (52.8)	12.44 ± 0.09 (61.3)	11.25 ± 0.40* (56.8)
3	Bioaccessible Iron (mg)	0.24 ± 0.01 (3.32)	0.25 ± 0.01^{ns} (3.36)	0.28 ± 0.02 (3.92)	0.32 ± 0.01* (4.29)	0.44 ± 0.02 (5.06)	0.40 ± 0.01* (4.03)
4	Bioaccessible Zinc (mg)	0.61 ± 0.05 (22.03)	0.62 ± 0.03^{ns} (24.15)	0.38 ± 0.07 (10.54)	0.43 ± 0.04* (14.92)	0.60 ± 0.18 (18.51)	0.53 ± 0.03* (14.72)
5	Bioaccessible Calcium (mg)	15.6 ± 0.47 (7.98)	17.6 ± 1.80^{ns} (7.04)	21.0 ± 0.72 (12.18)	24.9 ± 0.45* (15.35)	23.4 ± 0.65 (17.22)	16.4 ± 0.48* (10.7)

Means with superscript '*' are statistically significant at $p < 0.05$, ns - not significant. Figures in the parenthesis represent percent value in relation to total.

Table No.4: Functional properties of organic and non-organic legumes flours

S.No	Property	Horse Gram		Moth Bean		Red kidney beans	
		Organic	Non-organic	Organic	Non-organic	Organic	Non-organic
1	WAC (g/100g)	142.6 ± 1.0	150.1± 6.9^{ns}	85.4 ± 2.9	93.3 ± 6.0*	132.8 ± 0.0	139.6 ± 11.8^{ns}
2	WSI (g/100g)	12.0 ± 0.00	10.0 ± 0.01*	13.0 ± 0.01	12.0 ± 0.01^{ns}	20.6 ± 0.00	19.4 ± 0.07*
3	OAC (g/100g)	85.2 ± 1.4	85.2 ± 0.7^{ns}	84.8 ± 2.4	81.2 ± 1.8^{ns}	95.4 ± 0.8	95.4 ± 1.5^{ns}
4	Emulsion Activity (%)	17.8 ± 1.6	14.7 ± 0.8*	35.4 ± 0.2	20.4 ± 0.6*	9.6 ± 0.6	6.3 ± 0.6*
5	Emulsion Stability (%)	54.5 ± 1.8	54.4 ± 0.4*	27.4 ± 1.2	24.3 ± 0.6*	76.8 ± 3.6	64.2 ± 1.6*
6	Bulk Density (g/100ml)	84.8 ± 0. 6	83.9 ± 0.1*	83.9 ± 0.1	89.3 ± 0.8*	71.6 ± 0.4	77.3 ± 0.2*

Means with superscript '*' are statistically significant at $p < 0.05$, ns - not significant.

Table No.5: Foam capacity and foam stability of organic and non-organic legumes flours

S.No	Property	Horse Gram		Moth Bean		Red kidney beans	
		Organic	Non-organic	Organic	Non-organic	Organic	Non-organic
1	Foam Capacity (%)	55 ± 0.9	52.8 ± 0.8*	64.1 ± 1.6	63.7 ± 1.0^{ns}	68.1 ± 1.1	67.4 ± 1.1^{ns}
Foam Stability (%)							
	15 min	52.2 ± 1.6	50.6 ± 0.8^{ns}	60.7 ± 4.1	59.9 ± 3.3^{ns}	63.7 ± 1.0	64.6 ± 1.8^{ns}
2	30 min	50.6 ± 0.8	50 ± 1.6^{ns}	57.3 ± 2.5	58.3 ± 2.5^{ns}	55 ± 0.9	57.9 ± 1.7*
3	45 min	48.4 ± 0.8	47.3 ± 2.3^{ns}	51.7 ± 0.8	50 ± 1.6^{ns}	43.4 ± 1.5	47.2 ± 0.7*
4	60 min	44 ± 0.7	44 ± 0.7^{ns}	49.4 ± 0.8	44 ± 0.7*	43.4 ± 1.5	44.4 ± 1.5^{ns}
5	90 min	39 ± 1.4	41.8 ± 0.6*	36 ± 0.6	33 ± 0.5*	42.9 ± 2.2	20.2 ± 0.3*
6	120 min	33 ± 0.5	35.2 ± 0.5*	29.2 ± 0.5	19.2 ± 1.1*	26.4 ± 0.4	18 ± 0.3*

Means with superscript '*' are statistically significant at $p < 0.05$, ns - not significant.

Table No.6: Total phenols and flavonoid content and antioxidant activity in organic and non-organic legumes flours

S.No	Parameters	Horse Gram		Moth Bean		Red kidney beans	
		Organic	Non-organic	Organic	Non-organic	Organic	Non-organic
1	Total phenols (mg /g)	9.75±0.34	9.61±0.72^{ns}	4.65±0.36	4.89±0.30^{ns}	4.81±0.38	5.28±0.27^{ns}
2	Flavonoids (mg /g)	1.64±0.14	1.45±0.07*	0.08±0.01	0.08±0.00^{ns}	0.53±0.01	0.75±0.03*
3	Free radical scavenging activity (µmol /g)	74.7 ±1.4	75.2 ±0.7^{ns}	64.4 ±1.2	62.2±0.8^{ns}	57.6 ±1.9	58.7±0.2^{ns}
4	Ferric reducing antioxidant power (mM /g)	0.16±0.01	0.19±0.01*	0.25±0.0	0.22±0.01^{ns}	0.08±0.01	0.09±0.01^{ns}
5	Metal chelating Activity (µmol /g)	2.34±0.09	2.27±0.01^{ns}	1.77±0.09	1.60 ±0.00*	1.88±0.06	1.98±0.00*

Means with superscript '*' are statistically significant at $p < 0.05$, ns - not significant.

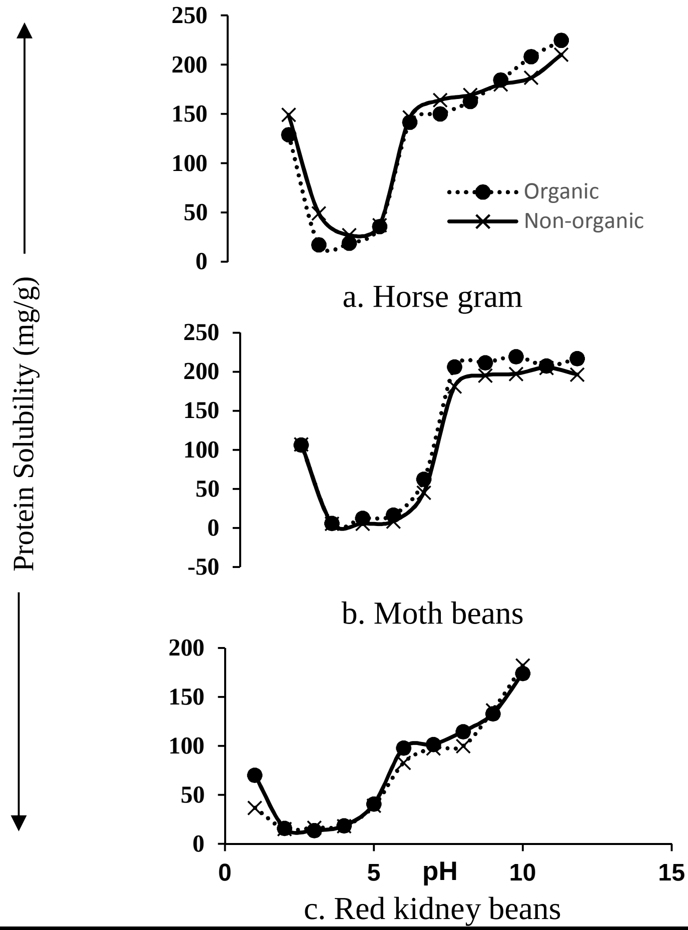

Figure No.1: Nitrogen Solubility of organic and non-organic legumes flours

CONCLUSION

The results of the study reveal that there were some differences observed in nutritional, functional and antioxidant properties of organic and conventionally grown legumes, however these differences depended upon the type of legume, and there were no specific traits or trends observed.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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