e-ISSN:2321-6204
p-ISSN:2347-2359

Research & Reviews: Journal of Food and Dairy Technology

Functional Properties of Dehulled Red Gram and Lentil Sourced from Organic and Non-Organic Sources: A Comparative Evaluation

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Research Article

Received Date: 09/03/2016

Accepted Date: 07/07/2016

Published Date: 14/07/2016

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Keywords: Nutrient composition, Water absorption, Oil absorption, Foaming capacity, Emulsion properties, Protein solubility.

ABSTRACT

The functional properties of the selected legume flours from organic and non-organic sources were studied. The chosen legume samples were decorticated red gram (*Cajanus cajan*) and lentil (*Lens culinaris*). The legume flours were analysed for nutrient composition and functional properties i.e. bulk density, nitrogen solubility, water absorption capacity (WAC), water solubility index, oil absorption capacity (OAC) and foaming and emulsion capacity. The nutrient composition of the red gram and lentil samples did not show significant differences in fat, ash and dietary fiber, but their protein content was slightly more in organic lentil samples. The iron, calcium and phosphorous contents of the non-organic legumes were higher in comparison with organic samples. Organic pulses showed significantly lower WAC than non-organic samples. OAC of the organic samples was significantly high when compared with non-organic legumes. The emulsion capacity did not differ significantly between organic and non-organic samples. The solubility of the protein increased at alkaline pH and all legume samples showed highest solubility (> 80%) at pH 11.0. The organic samples showed higher solubility than the non- organic legumes. The method of growing did not affect the nutritional composition of legumes to a greater extent, however, differences in functional properties were observed.

INTRODUCTION

Food behaviour and eating pattern evolve themselves over time depending upon scientific growth, technology and availability of information. Over the years consumers have come to demand "heath foods" on account of increased awareness and one of the trend is purchase of foods free from any kind of chemical additive (natural form). In this context, consumers prefer consumption of organic food products over non-organic foods which have created an increase in demand of organic foods in market. Consumer's perception is that organic foods are healthy foods which possess higher nutritional quality and protective phytochemicals compared to non-organic foods [1]. A review comparing studies on organic and inorganic crops by Worthington [2] reported that organic crops contained around 20 - 30% more of vitamin C, iron, magnesium, and phosphorus than inorganic crops. Organic farming has limited use for insecticides, herbicides, and fungicides and organic crops develop their own chemical defence mechanism resulting in increase in production of antioxidants such as plant polyphenolics [3]. Another aspect of organic food production is to encourage and enhance biological cycles within the farming system to maintain and increase long-term fertility of soils and to minimize all forms of pollution [4].

Legumes have been used since ancient times as a primary nitrogen source across a range of agricultural settings since they enhance the productivity and potential sustainability of farming system [5]. They provide the major protein component in human diets particularly in vegetarian diet. The use of plant proteins in food formulation largely depends upon their functional attributes [6]. Functional properties of macromolecules such as proteins define their end use in product as they influence many quality characteristics. Hence measurement of functionality of proteins in terms of emulsion capacity, foaming capacity, water holding and oil holding capacities and protein solubility is a prerequisite for protein foods. For example water absorption capacity of flour shows the extent of their interaction with water. The properties may also vary depending upon the pre and post-harvest, cultivar, growing conditions and various treatments the food is subjected to. On the basis of these properties, the specific protein selected to be used in a certain food will depend on its required function in the final product [7].

Among the different legumes, decorticated red gram (*Cajanus cajan*) and lentil (*Lens culinaris*) are the common ones often used in Indian curry preparation. The present study, aimed to investigate the functional and nutritional properties of organically and inorganically grown legumes.

MATERIALS AND METHODS

Materials

The decorticated red gram and lentil samples were collected from two different sources. The organic samples were procured from certified organic store and non-organic samples were procured from the local market of Mysore, India and cleaned for any foreign materials and ground into fine powder and passed through 250 μm sieve. The obtained flours were packaged in polyethylene (PE) pouches and stored below 4°C until used. All the chemicals and reagents used were of analytical grade.

Nutrient composition

The decorticated organic and non-organic red gram and lentil flours were analysed for nitrogen by Kjeldahl method and the value converted to protein by using Nx6.25, fat was estimated by Soxhlet method, ash content was determined by complete incineration of organic matter using muffle furnace and moisture content was determined by oven drying method by following the standard procedures of AOAC [8]. The total dietary fibre (TDF) was determined by rapid enzymatic assay [9]. Briefly, the enzymatic hydrolysis was performed by taking 1.0 g of sample, gelatinizing in the presence of Termamyl (heat stable α-amylase) (100 mg, boiled for 15 min, pH 6.0), treated with pepsin (100 mg, 40°C, 60 min, pH 1.5) and incubation with pancreatin (100 mg, 40°C, 60 min, pH 6.8). The insoluble dietary fibre (IDF) was recovered by filtration with celite as a filter aid. Soluble dietary fibre (SDF) was then precipitated from the filtrate with four volumes of 95% ethanol and recovered by filtration. The analytical values were evaluated from the mean of three determinations for each sample.

Functional properties

The decorticated organic and non-organicred gram and lentil flours were dried at 40°C for 24 hrs to attain equilibrium moisture and the samples were further used for determination of functional properties.

Bulk density (BD)

The flour bulk density was estimated using the method of Okezie and Bello [10], briefly a 10 ml graduated cylinder, previously tared was gently filled with the sample up to 5 ml mark by tapping it on a bench top, then it was filled up to 10 ml mark by tapping until there is no further diminution of the sample. The weight of the cylinder was taken and the bulk density was calculated as the weight of sample per unit volume of sample (g/100 ml).

Water absorption capacity (WAC)

WAC of the legume flour were determined following the procedure of Elhardallou and Walker [11] and reported as the g of water absorbed/100 g of the dry flour.

Water solubility index (WSI)

The water solubility index (WSI) was measured according to the method of Anderson et al. [12] and calculated from the weight ratio of dissolved solids in the supernatant and dry sample.

Oil absorption capacity (OAC)

Oil absorption capacity of the legume flours were determined by the method of Sosulski et al. [13] and reported as the g of oil absorbed/100 g of the dry flour.

Nitrogen solubility

The soluble nitrogen content of legume flours was determined at different pH from 2-11 by adjusting the pH with 0.1 M HCl and 0.1M NaOH. The amount of protein in the supernatant was determined by using Barford reagent (Sigma–Aldrich chemical company, St. Louis, USA). The soluble protein was expressed in mg/g of flour sample.

Foaming and emulsifying properties

Foam capacity (FC) and foam stability (FS) were determined according to the method of Coffmann and Garcia [14]. The volume of the foam was recorded as foam capacity and monitored at regular intervals for 60 min to evaluate stability. Emulsion activity (EA) and emulsion stability (ES) were evaluated by using the method of Yasumatsu et al. [15].

Statistical analysis

One-way ANOVA was used to analyse the significant difference between the results of different samples. Multiple comparisons were made for all experiments employing Duncan's multiple range test (DMRT) at the 5% level of significance.All statistical analyses were performed using statistical software Statistica'99 (StatSoft, Tulsa, OK, USA).

RESULTS AND DISCUSSION

Nutritional composition

The proximate composition of organic and non-organic decorticated red gram and lentil samples are presented in **Table 1.** Non-organic lentil (10.7%) had highest moisture, however no significant differences were observed among the other legumes. The protein content of legume samples ranged between 22.3-27.9 g/100 g, lentil samples showed significantly higher protein content than red gram. The organic lentil (27.9%) exhibited slightly higher protein content than non-organic lentil (27.3%), whereas in red gram the non-organic sample exhibited higher protein content. Results of non-organic samples were comparable with earlier reports on red gram by Khatoon and Prakash [16], and lentil by Meiners et al. [17]. The fat content of the red gram was significantly higher than lentil samples and between organic (2.1%) and non-organic (2.0%), differences were non-significant. However, in organic (1.0%) and non-organic lentil (1.9%) samples, a significant difference was found. Ash content of legume samples was in the range of 2.6 - 3.9%, with red gram showing significantly higher ash content than lentil. There was no significant difference between ash content of organic (3.8%) and non-organic (3.9%) red gram, but significant differences were observed in organic (2.6%) and non-organic (2.9%) lentil. The fat and ash values are similar to literature values of Aletor and Aladetimi [18] and Meiners et al. [17] for red gram and lentil respectively.

Table 1. Proximate composition of the decorticated organic and non-organic red gram and lentil (db).

Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Dietary Fibre (%)			NSC* (%)
					Insoluble	Soluble	Total	
Red gram (Organic)	9.0 ± 0.1^{a}	22.3 ± 0.0^{a}	2.1 ± 0.1^{b}	3.8 ± 0.1^{c}	9.3 ± 0.2^{b}	4.3 ± 0.1^{c}	13.6 ± 0.3^{b}	58.1^{b}
Red gram (Non-organic)	9.2 ± 0.1^{a}	23.6 ± 0.2^{b}	2.0 ± 0.0^{b}	3.9 ± 0.1^{c}	9.1 ± 0.1^{b}	4.7 ± 0.2^{c}	13.9 ± 0.2^{b}	56.7^{a}
Lentil (Organic)	9.3 ± 0.4^{a}	27.9 ± 0.0^{d}	1.0 ± 0.0^{a}	2.6 ± 0.0^{a}	7.4 ± 0.0^{a}	2.9 ± 0.2^{b}	10.3 ± 0.2^{a}	58.2^{b}
Lentil (Non-organic)	10.7 ± 0.4^{b}	27.3 ± 0.2^{c}	1.9 ± 0.3^{b}	2.9 ± 0.0^{b}	7.5 ± 0.1^{a}	2.4 ± 0.2^{a}	9.9 ± 0.3^{a}	58.0^{b}

Means with different superscript within the same column for each flour are significantly different at p≤ 0.05. By difference, NSC-Non-structural carbohydrates, db: dry weight basis.

The TDF content of legumes ranged from 9.9-13.9%. Red gram (13.9%) exhibited significantly higher TDF than lentil (10.3%), however, there was no significant difference in the TDF content of organic and non-organic legumes. IDF, which comprises of lignin, cellulose and hemicelluloses, was high in red gram (9.3%) and followed similar trend like TDF. The SDF was found to be high in red gram (4.7%) than lentil (2.9%). The dietary fibre values were slightly higher than the literature values [16] but followed a similar trend. This may be due to varietal and climatic differences between the samples. Dietary fibre intake has a beneficial role in the prevention of diseases including cardiovascular disease, diabetes, cancer and weight regulation [19-21]. Keeping in mind that soluble fibre has the potential to reduce cholesterol concentration, mainly by lowering LDL cholesterol [22], legumes such as red gram can be of interest when developing products for dietary treatment of cardiovascular disorders. The non-structural carbohydrates were in the range of 56.7-58.2%, the non-organic red gram showed the lowest non-structural carbohydrates (56.7%), whereas no significant differences were observed between other legumes.

The mineral content of the legume flours is presented in **Table 2.** Calcium, iron and phosphorus were estimated. The calcium content of the red gram was significantly higher than lentil. Non-organic red gram and lentil (56.0 and 47.0 mg/100 g respectively) showed significantly higher calcium content than organic counterpart (53.0 and 45.0 mg/100 g respectively). The iron content of lentil sample was found to be higher than red gram samples. Lentil samples followed similar trend like calcium for the organic and non-organic samples i.e. non-organic samples showed higher iron content than organic samples. The phosphorus content of non-organic samples was significantly higher than organic samples this may be due to use of the phosphorus containing fertilizers in farming of the non-organic samples. These values were slightly higher than earlier reports [16,23] which may be due to the varietal and climatic differences and growing conditions.

Table 2. Mineral content of the decorticated organic and non-organic red gram and lentil (mg/100 g)

Samples	Calcium	Iron	Phosphorous
Red gram (Organic)	53.0 ± 0.8^{c}	4.49 ± 0.06^{a}	357.0 ± 2.89^{a}
Red gram (Non-organic)	56.0 ± 1.1^{d}	5.88 ± 0.06^{b}	398.0 ± 0.83^{c}
Lentil (Organic)	45.0 ± 0.8^{a}	7.90 ± 0.08^{c}	382.0 ± 1.67^{b}
Lentil (Non-organic)	47.0 ± 0.3^{b}	8.84 ± 0.05^{d}	395.0 ± 3.33^{c}

Means with different superscript within the same column for each flour are significantly different at p≤ 0.05.

Functional properties

The functional properties of organic and non-organic red gram and lentil are presented in **Table 3** and **Figures 1-2.** Bulk density is a physical property which indicates the weight/volume ratio of any material and is needed for packaging requirements. The bulk density (BD) ranged from 75.6-85.0 g/100 ml. Lentil samples showed significantly higher BD than red gram. In red gram, the organic sample (75.7g/100 ml) had lower BD than non-organic (79.6 g/100 ml), while in lentil the organic (85.0 g/100 ml) exhibited higher BD than the non-organic (80.6 g/100 ml). The BD of the non-organic lentil was similar to what was reported by Ghavidel and Prakash[6].

Table 3. Functional properties of the decorticated red gram and lentil between organic and non-organic varieties.

Functional property	Red gram (Organic)	Red gram (Non-organic)	Lentil (Organic)	Lentil (Non-organic)
Bulk density (g/100 ml)	75.6 ± 0.3^a	79.6 ± 0.5^b	85.0 ± 0.6^d	80.6 ± 0.8^c
Water absorption capacity (g/100 g)	76.1 ± 1.2^a	105.2 ± 6.3^c	90 ± 4.5^b	110.8 ± 3.5^c
Water solubility index (g/100 g)	24.0 ± 1.1^a	21.0 ± 2.2^a	24.0 ± 0.9^a	25.0 ± 1.1^a
Oil absorption capacity (g/100 g)	87.1 ± 1.8^c	81.3 ± 0.0^a	83.1 ± 1.1^b	80.8 ± 0.5^a
Emulsion activity (ml/100ml)	43.1 ± 0.8^a	42.9 ± 0.8^a	44.3 ± 0.9^a	44.2 ± 1.2^a
Emulsion Stability (ml/100 ml)	95.1 ± 0.9^a	93.7 ± 0.7^a	97.5 ± 1.3^b	93.0 ± 1.6^a
Foam Capacity (ml/100 ml)	53.9 ± 0.9^b	48.4 ± 0.8^a	67.0 ± 1.5^c	85.7 ± 4.4^d

^{a}Means with different superscript within the same row for each flour are significantly different at $p \leq 0.05$.

Water absorption capacity and water solubility index

Water absorption capacity is the quantity of water absorbed by the flour to achieve the desired consistency or optimal end result. Machinability, proofing, loaf volume, the final product attributes and shelf life are each vital elements directly affected by water absorption. The water absorption capacity (WAC) of legumes was in the range of 76.1 - 110.8 g/100 g. Organic legumes exhibited significantly lower WAC than non-organic samples. Among all the organic red gram (76.1 g/100 g) exhibited lowest WAC followed by organic lentil (90.0 g/100 g). The WAC of the non-organic lentil can be compared with previous report of Ghavidel and Prakash [6], whereas the WAC of red gram was slightly lower than the literature value [24]. According to Hodge and Osman [25], flours with high water absorption have more hydrophilic constituents, such as polysaccharides. It is known that polar amino acid residues of proteins have an affinity for water molecules and differences in WAC of different legumes could be due to the changes in content of these amino acids [26]. Water solubility index (WSI), which is related to the presence of soluble molecules, differed significantly between various legume flours. The WSI of legume samples ranged from 21- 25 g/100 g, no significant differences in WSI were observed between legume samples. The WSI of the non-organic red gram (21.0 g/100 g) was slightly higher when compared with report of Maninder et al. [27] on red gram (14.5 g/100 g).

Oil absorption capacity

Oil absorption capacity (OAC) is attributed to the physical entrapment of oil, which is important since oil acts as flavour retainer and increases the mouth feel of food. The OAC of legume samples were in the range of 80.8 - 87.1%. Organic red gram (87.1%) and lentil (83.1%) showed significantly higher OAC than non-organic red gram (81.3%) and lentil (80.8%) samples. This may be due to the fact that binding of the lipid depends on the surface availability of non-polar side chains of proteins [13]. The organic samples showed higher OAC, and this may be the reason for better organoleptic properties of the organic foods when compared to the non-organic foods. The OAC of red gram and lentil were slightly lower than the literature value [6,27].

Emulsion activity and stability

Emulsion activity is the ability of the protein to participate in emulsion formation and to stabilise the newly formed emulsion. The emulsion activity (EA) and stability (ES) of the organic and non-organic red gram and lentil are presented in **Table 3.** Lentil samples exhibited significantly higher EA than red gram and there were no significant differences between organic and non-organic samples. The emulsion activity of the samples was slightly less than the earlier reports of Oshodi and Ekperigin [24], and Ghavidel and Prakash [6]. The legumes exhibited 93.5 - 97% emulsion stability. Organic red gram (95.1%) and lentil (97.5%) showed higher emulsion stability than non-organic samples (93.7 and 93.0% respectively). The samples showed higher ES than previous report on lentil [6]. The emulsion stability normally reflects the ability of the proteins to impart strength to an emulsion for resistance to stress and therefore related to the consistency of the interfacial area over a defined time period [28].

Foam capacity and stability

The property of proteins to form stable foams is important in the production of a variety of foods. Foam can be defined as a two-phase system consisting of air cells separated by a thin continuous liquid layer called the lamellar phase. Food foams are multifaceted structures, which includes a mixture of gases, liquids, solids, and surfactants. The size dispersal of air bubbles in foam influences the foam product's look and textural properties; foams with a uniform distribution of small air bubbles imparts body, smoothness, and lightness to the food. Foam capacity (FC) of organic and non-organic legume samples are presented in **Table 3.** Organic (67.0%) and non-organic (85.7%) lentil samples showed significantly greater FC than organic (53.9%) and non-organic (48.4%) red gram. In red gram, organic sample exhibited higher FC than non-organic sample, but in lentil the non-organic sample showed higher foam capacity. The foam stability of the legume samples is shown in **Figure 1.** The organic red gram and lentil showed significantly higher foam stability than non-organic red gram and lentil samples. The samples exhibited higher FC and FS than the previous reports [6,24]. Foam formation and stability generally depend on the interfacial film formed by proteins, which keeps the air bubbles in suspension and slows down the rate of coalescence. Stable foams are known to occur when low surface tension and high viscosity occur at the interface, forming a continuous cohesive film around the air vacuoles in the foam. Foaming properties are dependent on the proteins, as well as on other components, such as carbohydrates present in the flour. Proteins in foams contribute to the uniform distribution of fine air cells in the structure of foods. Body and smoothness of food foams is related to the formation of air bubbles that allow volatilization of flavors with enhanced palatability of the foods. These differences may be due to the changes in the protein and other components between the organic and non-organic samples.

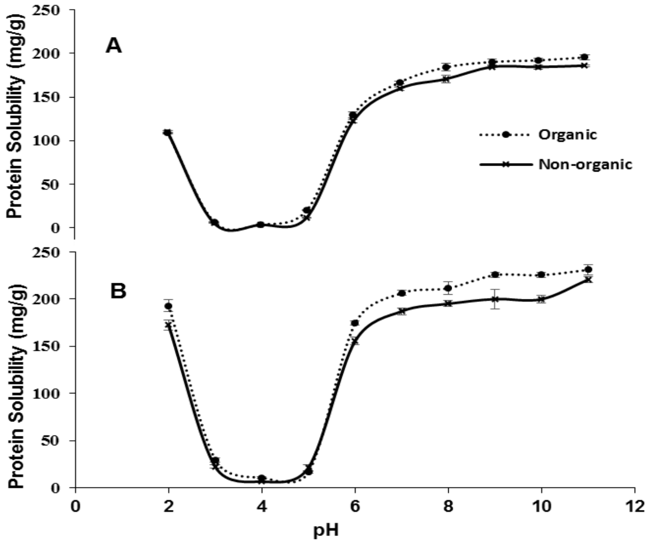

Figure 1. Foam stability of organic and non-organic legume flours.

Protein solubility

The solubility of proteins is considered as that quantity of nitrogen in a protein product which is soluble state under specific conditions. Solubility is the quantity of protein in a food sample that dissolves into solution. Proteins recommended as food additives can be partly or completely soluble or completely insoluble in water. The protein solubility of the legume samples is presented in **Figure 2.** Red gram exhibited less protein solubility than lentil at pH-2. There was no significant difference in nitrogen solubility of red gram in acidic pH, but a slight increase in protein solubility of organic lentil was observed. The iso-electric point for both legume samples which showed least solubility was at pH-4, similar observations were reported by Rajesh and Prakash [29]. They worked on enzyme hydrolysed albumin fractions of red gram and lentil and found that enzymic treatments reduced the protein solubility of both samples slightly, though major differences were not observed [29]. The solubility of the protein increased at alkaline pH and all legume samples showed highest solubility (>80%) at pH 11.0. These observations are typical of legume and oilseed proteins and have been reported earlier. Thermal and enzymic treatments have been reported to affect the water and fat absorption capacities and protein solubility of legumes [29-32]. The organic samples showed higher solubility than the non-organic legumes. The results are in agreement with the earlier reports on red gram and other legumes [6,24]. The knowledge on protein solubility can give useful information on the potential utilization of proteins and their functionality, especially in foams, emulsions and gels. Solubility is the main characteristic of the protein selected for the use in liquid foods and beverages [33].

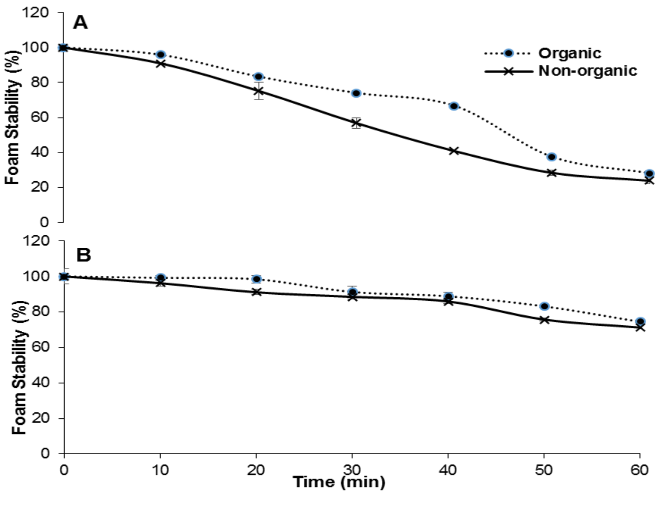

Figure 2. Nitrogen solubilities of organic and non-organic legume flours at different pH A) Red gram B) Lentil.

ACKNOWLEDGEMENT

The authors acknowledge the financial support from DST-PURSE project for research and Dr. Ravishankar Rai, Project Coordinator for his support and encouragement.

CONCLUSION

Legumes from different sources i.e, organic and non-organic sources did not exhibit greater differences in their nutrition composition, however slight increase in the protein content was observed. The dietary fibre content of the red gram was found to be higher than lentil and no significant differences were observed between organic and non-organic sources. The mineral content of the lentil samples found to be high when compared with red gram and non-organic legumes showed greater mineral contents than organic legumes. The functional properties exhibited differences between organic and conventional sources. WAC of the non-organic samples was greater than the organic samples, whereas the OAC of the organic legumes was found higher. The protein solubility and the foam stability of the organic legumes were superior when compared with non-organic legumes. In conclusion, the method of growing did not alter the nutritional composition to a larger extent but changes in the functional properties were observed.

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