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Physico-chemical properties of selected dehulled legumes incorporated rice extrudates using collet extruder

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ABSTRACT

Protein enriched ready-to-eat extrudates were made of rice grit by incorporating from selected dehulled legumes at different levels (0, 5, 10 and 15%), respectively. Physical properties viz., expansion index, sectional expansion index, bulk density, true solid density of extrudates were found to be in the range of 4.00 to 3.17, 16.00 to 10.03, 0.79 x 10^4 to 0.622 x 10^4 g/mm^2, and 1.39 x 10^4 to 1.052 x 10^4 g/mm^3, respectively. Textural properties viz., hardness, puncture force, breaking force and breaking strength were found to be in the range of 22.22 g to 65.71 g, 5.95 g to 27.46 g, 15.87 to 25.32 g and 0.079 to 0.181 g/mm^2. L-value showed a decreasing trend, whereas a and b values followed an increasing trend with legume incorporation levels. WAI and WSI were found to be in the range of 339 to 453% and 20.2 to 25.2%, respectively. Sensory evaluation

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scores showed the most liking range (6 to 8). Thus, legumes incorporation (up to 15%) showed higher overall acceptability except black gram.

Keywords: Extrusion, Legumes, Rice, Physical properties, Textural properties

1 Introduction

Extrusion cooking has been extensively reviewed by various researchers (Parker, Hassell, Mottram, and Guy, 2000; Eastman, Orthoefer, and Solorio, 2001) due to notable advantages. Advent of extrusion cooking has helped to develop extruder and food products at low-cst for developing countries (Balasubramanian and Singh, 2007; Borah et al 2019). There are number of low protein snacks (2.44-11.06%) in market (Plernchai, Patcharee, and Wanpen mesomya, 1999) which need to be improved in terms of textural attribute and nutrition profile.

Rice (*Oryza sativa*) has been popularly used for making traditional food products and adition with legumes increases both amount and quality of the protein mix (Borah, mahanta and Kalita, 2016; Cheftel, Cuq and Lorient, 1989) .The physical properties viz., bulk density and expansion index of extruded products describe its degree of puffing (Park, Rhee, Kim, and Rhee, 1993). Textural properties represent the resistance offered by extrudates during its deformation and offer the understanding of product suitability for packaging. Many factors affect preference and acceptability of extruded products. Thus, the intrinsic and extrinsic factors to product are appearance, taste, flavor, social and cultural (Deliza, Macfie, and Hedderley, 1996). Hence, the investigation was undertaken

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to study effect of incorporation of dehulled legumes with rice grits in extrudates production using collet extruder.

2. Materials and methods

2.1. Raw materials and preparation

Raw materials selected for this study were broken raw rice (*Oryza sativa*), and dehulled legumes viz., black gram (*Phaseolus mungo roxb*), green gram (*Phaseolus aureus roxb*), lentil (*Lens esculenta*) and peas (*Pisum sativum*). Raw materials were cleaned and ground by multipurpose grinder to pass through sieve (ASTM No. 28).

2.2. Extrusion cooking condition

Extrusion cooking has been done in a heavy-duty collet extruder (BTPL, India) at a constant feed rate of 500 rpm at constant feed rate (25 kg/h), respectively (Table 1).

2.3. Physical properties

Expansion index (EI) is the ratio of extrudates diameter to die diameter. A digital vernier caliper (Digimatic, Mitutoyo, Japan) was used to measure the diameter of extrudates.

Bulk density was calculated by dividing weight of extrudate by container volume.

$$\text{Bulkdensity (g/mm}^3) = \frac{(\text{weight of extrudates} + \text{weight of container}) - (\text{weight of container})}{\text{Volume of container}}$$

True solid density (TSD) of extrudate was calculated as mass per volume (Onwulata, Smith, and Konstance, 2001).

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$$\text{True solid density}\,(g/mm^3) = \frac{(\text{weight of extrudates})}{(\text{volume of mustard} + \text{extrudate}) - (\text{volume of mustard})}$$

2.4. Textural properties

Textural properties of extrudates were assessed with appropriate settings (Table 2) using Texture Analyzer (Model- TA-HD*i*, Stable micro, UK). Hardness (H), puncture force (PF) and breaking force (BF) were read from force-time plot. Breaking strength (three point cutter) was calculated by using Eq. (6):

$$\text{Breaking strength}\,(g/mm^2) = \frac{\text{peak breaking force}}{\text{cross sectional area}}$$

2.5. Hunter color values

L, a and b- values of ground extrudate (20 mesh ASTM) were measured using Hunter Colorimeter (NR-3000, $10^o/D_{65}$).

2.6. Water absorption index (WAI) and water solubility index (WSI)

The method of Singh and Smith, (1997) was adopted for determination of WAI and WSI, respectively.

2.7. Sensory attributes

Sensory score was evaluated by using 9 point Hedonic scale.

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3. Results and discussion

Physico-chemical properties of dehulled legumes incorporated rice extrudates are shown in Fig. 1. Regression models of relationship between dehulled legumes incorporation levels and extrudates properties are summarized in Table 3.

3.1. Expansion and sectional expansion index

It can be observed (Fig.1), maximum expansion index (4.0) was found for rice extrudates without legumes incorporation followed by 5, 10 and 15% legumes incorporation levels. It has been noted that expansion index decreased with increase in dehulled legumes incorporation levels, irrespective of legume types. At 15% incorporation level, expansion index of black gram was found maximum (3.50), followed by lentil (3.33), green gram (3.25) and peas (3.17). The decreased expansion ratio might be due to higher protein levels and fiber. Also, degree of expansion was correlated with number of air cells on smooth walls of extrudate (Balasubramanian, and Singh, 2007). Thus, for expansion index, the significant factor was found to be feed composition. Gopalan, Ramasastri, and Balasubramanian, **(**1991) reported high protein content (g/100 g) for dehulled legumes incorporated rice grits. Earlier studies have reported that EI of starch mostly depends on degree of gelatinisation (Chinnaswamy, and Bhattacharya, 1983). Similarly, Tang, and Ding (1992) reported that the expansion index depends on extrusion parameters may not exist a simple linear relationship between expansion and sectional expansion indices and the extent of macromolecular degradation. SEI is the square term of EI; hence these values were similar in explaining the extrudates behavior. Maximum sectional expansion index was found for rice extrudate (16.0). Decrease in SEI has been observed with increase in dehulled legumes incorporation levels, irrespective of

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legume types. Sectional expansion index at 15% incorporation of black gram was maximum (12.25), followed by lentil (11.11), green gram (10.56) and peas (10.03). Thus, inversely proportional relationships of sectional expansion index with protein levels profound the significance of feed composition in extrusion processing.

3.2. Bulk and true solid density

Bulk density of extrudates showed an increasing trend with legumes incorporation levels. The highest bulk density was found as 0.622 x 10^4 g/mm^2 in case of rice extrudates alone. Among legumes, the highest BD was observed for lentil followed by black gram, peas and green gram. BD and EI were reported to be interrelated (Park, Rhee, Kim, and Rhee, 1993; Falcone, and Phillips, 1988). The effect of legume types and incorporation levels on true solid density is illustrated in Fig. 1. True solid density varied from $1.39x10^4$ to $1.052x10^4$ g/mm^2. There was a higher increase in case of black gram and green gram with slight decrease for lentil and peas. Ding, Ainsworth, Tucker, and Marson (2005) reported that BD was mostly dependent on feed moisture. At higher protein levels, bulk density and true solid density were also high, that might have caused inadequate cooking to gelatinize or cook protein matrix with available moisture in extrusion process and resulted in reduced puffing. Due to this, the denser product was obtained.

3.2. Textural properties

Textural properties viz., hardness, puncture force, breaking force and breaking strength for extrudates are depicted in Fig. 2. Hardness values increased from 27.41 g (for rice extrudates) to 48.09 g, 52.91 g, 65.71 g and 55.84 g for black gram, green gram, lentil and peas incorporated rice extrudates, respectively. Among legumes, lentil and peas

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showed a higher hardness value for extrudates and positively correlated with bulk and true solid density and negatively correlated with expansion and sectional expansion of extrudates. These results indicated that the cellularity strongly influences mechanical or textural failure pattern and are reflective of sensory attributes. Similarly earlier studies have found that the compressive strength of corn extrudates was directly proportional to bulk density and inversely proportional to cell sizes (Barrette, and Peleg, 1992). It was evident that the extrudates with lower expansion and higher hardness values are relatively thicker cell walls with lower porosity expressed a greater resistance to compression. Puncture force values were ranged from 5.95 to 27.46 g for all dehulled legumes incorporated rice extrudates (Fig. 2.). Breaking force for rice extrudate was 15.87 g. Upon increasing legumes incorporation levels with rice grits in extrudate production resulted in higher breaking force. A maximum breaking force value (25.32 g) was found for 15% black gram incorporated rice extrudates. Thus, breaking force was directly proportional to other textural attributes, irrespective of legumes types. Breaking strength for rice extrudate was 0.079 g/mm^2. These values were also found to increase with increase of dehulled legumes. At 15% incorporation of all legumes, values of breaking strength were found to be 0.165, 0.181 0.172 and 0.191 g/mm^2 that indicated the optimal extrusion cooking conditions of minimum breaking strength.

3.3. Color attributes

The color values (L, a and b) for different dehulled legume incorporated rice extrudates are presented in Fig. 3. L-value was higher for rice extrudates alone (80.63). Among L-values of different incorporation levels, black gram incorporated rice extrudates exhibited higher values than other legume. L-values showed a decreasing trend

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with increase in protein levels. The decrease in L-value of extrudates with addition of all legumes incorporation indicated a decrease in lightness of extrudates. Hunter color a and b values were found to be minimal (1.82 and 11.66) for rice extrudates alone. Also, a and b values were found to be increased with increase in legumes incorporation levels. Berset (1989) reported that the extrusion cooking favor maillard reaction at high temperature and relatively low moisture. Though, maillard reaction normally involves reducing sugars and amino acids, the high shear forces during extrusion cooking enhances hydrolysis of starch by reducing carbohydrates (Chinachoti, 2000). Among many reactions during extrusion cooking, non-enzymatic browning reaction and pigment degradation are considered as important for increase in a and b values and reduced L-values, respectively.

3.4. Water absorption index and water solubility index

Fig. 4 showed that the WAI of legume incorporated extrudates was observed in the range 339-452%, and incorporation of legumes showed a marginal increase. At 15% incorporation level, extrudates showed a maximum WAI value of 391%, 451%, 417% and 452% for black gram, green gram, lentil and peas, respectively. Doxastakis, et al., (2002) reported that the increase in WAI for 5-15% defatted soya flour incorporated wheat flour. Incorporation of legumes showed a slight increase in WSI of extrudates, ranged between 20.20 to 25.02%. Maximum increase in WSI was observed for peas resulting 23.0%, 24.9% and 25.2% at 5%, 10% and 15% incorporation, respectively. Green gram and lentil incorporation showed a similar increase in WSI, having a maximum value of 24.7% and 24.2% were observed at 15% incorporation level. However, black gram incorporation showed no marginal change in WSI.

3.5. Sensory attributes

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From the Fig. 5, it was observed that the sensory score was moderately affected by selected dehulled legume incorporation. The color score were mostly affected by incorporation of lentil and pea. Overall acceptability score for legume incorporated rice extrudates were found to be better than rice extrudate alone.

4. Conclusion

The optimum level for the continuous extrudate production was up to 15% incorporation of legume at 14% wb moisture content. All the legume incorporated rice extrudates, except black gram showed higher hedonic scores having promising feature for production of protein enriched rice based extrudates using collet extruder. Therefore, cerealsin combination with legumes could be used for developing extrudates with better physicochemical properties, which could provide better nutrion too at a lower-cost.

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Table 1

Experimental design layout.

Cereals	Moisture content (% wb)	Dehulled Legumes (%, w/w basis)			
		Black gram	Green gram	Lentil	Peas
Rice	14	0/5/10/15	0/5/10/15	0/5/10/15	0/5/10/15

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Table 2

Different textural analysis test conditions.

Type of test	Hardness	Puncture force	Breaking force and breaking strength
Probe	P-75	P-5	HDP/BS
Strain/displacement	40%	40%	30 mm
Constant Load cell (kg)	5	5	5
Constant cross- head speed (mm/s)	1	1	1

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Table 3
Regression models for predicting different extrudates properties

Dependent variable	Type of legumes	Predictive model	Regression coefficient
EI	BG	$0.003x^2 - 0.083x + 4.00$	$R^2 = 0.99$
	GG	$0.002x^2 - 0.072x + 3.98$	$R^2 = 0.96$
	L	$-0.002x^2 - 0.053x + 4.07$	$R^2 = 0.80$
	P	$0.002x^2 - 0.085x + 4.03$	$R^2 = 0.95$
SEI	BG	$0.026x^2 - 0.632x + 15.99$	$R^2 = 0.99$
	GG	$0.015x^2 - 0.559x + 15.82$	$R^2 = 0.96$
	L	$0.016x^2 - 0.391x + 16.49$	$R^2 = 0.80$
	P	$0.014x^2 - 0.639x + 16.23$	$R^2 = 0.96$
BD	BG	$0.001x^2 + 0.002x + 0.62$	$R^2 = 0.99$
	GG	$-0.001x^2 + 0.012x + 0.62$	$R^2 = 0.97$
	L	$0.001x^2 - 0.005x + 0.62$	$R^2 = 0.99$
	P	$-0.001x^2 + 0.005x + 0.62$	$R^2 = 0.95$
TSD	BG	$-0.001x^2 + 0.011x + 1.06$	$R^2 = 0.92$
	GG	$0.001x^2 + 0.019x + 1.06$	$R^2 = 0.96$
	L	$0.003x^2 - 0.017x + 1.06$	$R^2 = 0.99$
	P	$0.003x^2 - 0.030x + 1.07$	$R^2 = 0.94$
H	BG	$0.037x^2 + 0.769x + 27.86$	$R^2 = 0.98$
	GG	$-0.090x^2 + 3.143x + 26.71$	$R^2 = 0.98$
	L	$0.014x^2 + 2.106x + 29.15$	$R^2 = 0.92$
	P	$0.134x^2 - 0.055x + 26.96$	$R^2 = 0.99$
PF	BG	$0.006x^2 + 0.969x + 11.10$	$R^2 = 0.95$
	GG	$-0.018x^2 + 1.409x + 10.46$	$R^2 = 0.99$
	L	$0.051x^2 + 0.358x + 10.54$	$R^2 = 0.99$
	P	$0.059x^2 + 0.139x + 11.34$	$R^2 = 0.91$
BF	BG	$-0.071x^2 + 1.632x + 16.31$	$R^2 = 0.93$
	GG	$0.012x^2 + 0.341x + 16.13$	$R^2 = 0.96$
	L	$0.039x^2 - 0.117x + 16.34$	$R^2 = 0.87$
	P	$0.069x^2 - 0.532x + 16.19$	$R^2 = 0.96$
BS	BG	$-0.001x^2 + 0.014x + 0.08$	$R^2 = 0.98$
	GG	$0.001x^2 + 0.004x + 0.08$	$R^2 = 0.96$
	L	$0.001x^2 + 0.001x + 0.08$	$R^2 = 0.99$
	P	$0.001x^2 - 0.005x + 0.08$	$R^2 = 0.90$
L	BG	$-0.003x^2 - 0.292x + 80.34$	$R^2 = 0.89$
	GG	$0.026x^2 - 0.740x + 80.40$	$R^2 = 0.94$
	L	$-0.052x^2 + 0.432x + 80.60$	$R^2 = 0.94$
	P	$0.014x^2 - 0.674x + 80.64$	$R^2 = 0.99$
a	BG	$0.001x^2 + 0.030x + 1.79$	$R^2 = 0.93$
	GG	$0.004x^2 + 0.007x + 1.80$	$R^2 = 0.98$
	L	$0.006x^2 - 0.050x + 1.87$	$R^2 = 0.89$
	P	$0.010x^2 - 0.043x + 1.85$	$R^2 = 0.98$
b	BG	$0.010x^2 - 0.067x + 11.71$	$R^2 = 0.95$
	GG	$-0.001x^2 + 0.108x + 11.68$	$R^2 = 0.99$
	L	$0.008x^2 + 0.126x + 11.62$	$R^2 = 0.99$
	P	$0.006x^2 + 0.172x + 11.70$	$R^2 = 0.99$
WAI	BG	$-1.924x^2 + 43.348x + 365.94$	$R^2 = 0.96$
	GG	$-1.720x^2 + 40.328x + 368.44$	$R^2 = 0.93$
	L	$-1.536x^2 + 35.648x + 364.44$	$R^2 = 0.96$
	P	$-0.560x^2 + 22.864x + 350.52$	$R^2 = 0.97$
WSI	BG	$-0.276x^2 + 10.500x + 236.50$	$R^2 = 0.99$
	GG	$0.828x^2 - 6.364x + 238.78$	$R^2 = 0.96$
	L	$-0.056x^2 + 17.320x + 238.40$	$R^2 = 0.99$

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P	$-1.152\ x^2 + 48.384\ x + 247.32$	$R^2 = 0.98$

BG: Black gram, GG: Green gram, L: Lentil, P: Peas, x: legume incorporation level

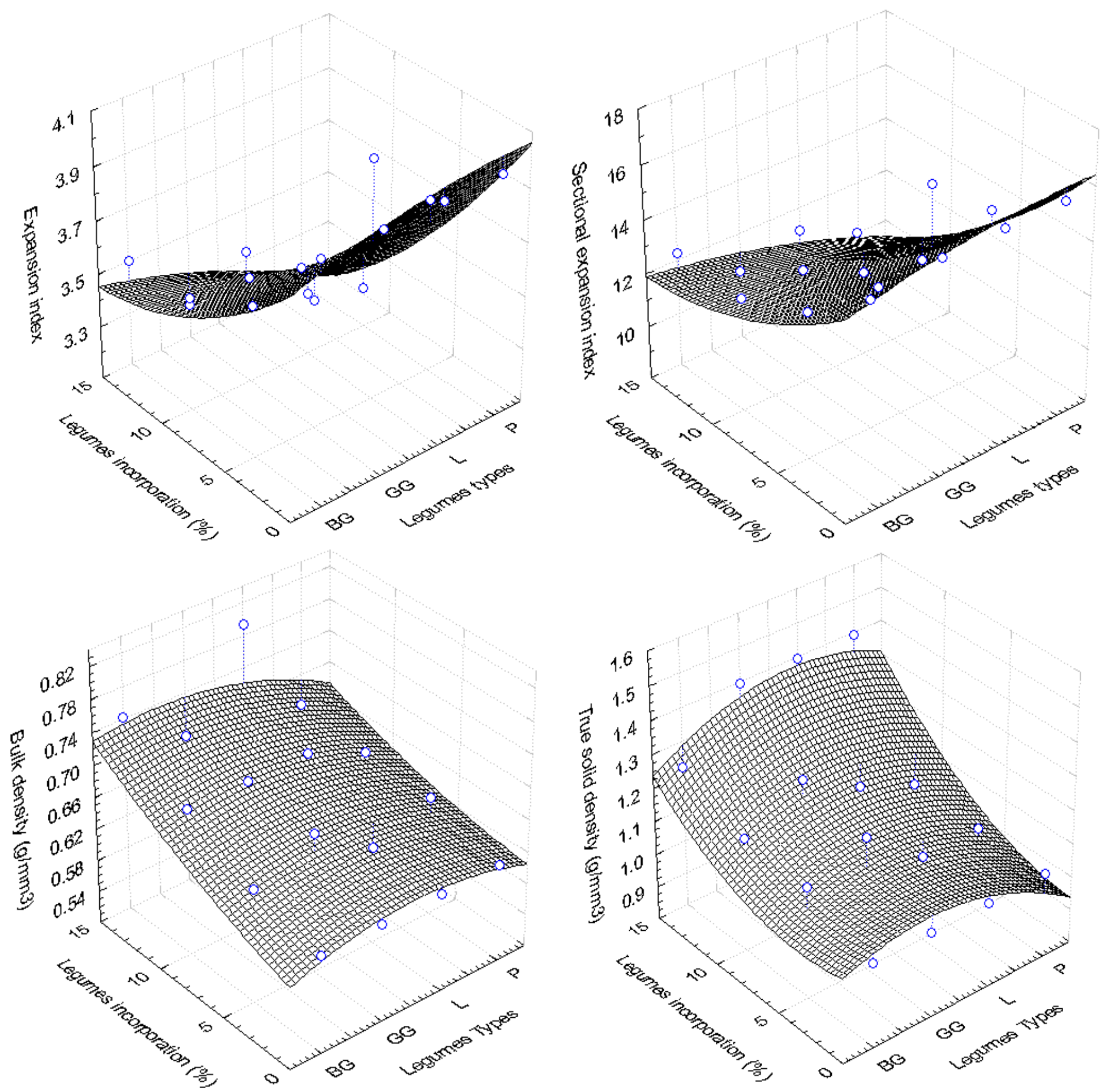

Fig. 1. Physical properties of dehulled legumes viz., black gram (BG), green gram (GG), lentil (L) and peas (P) incorporated with rice grits.

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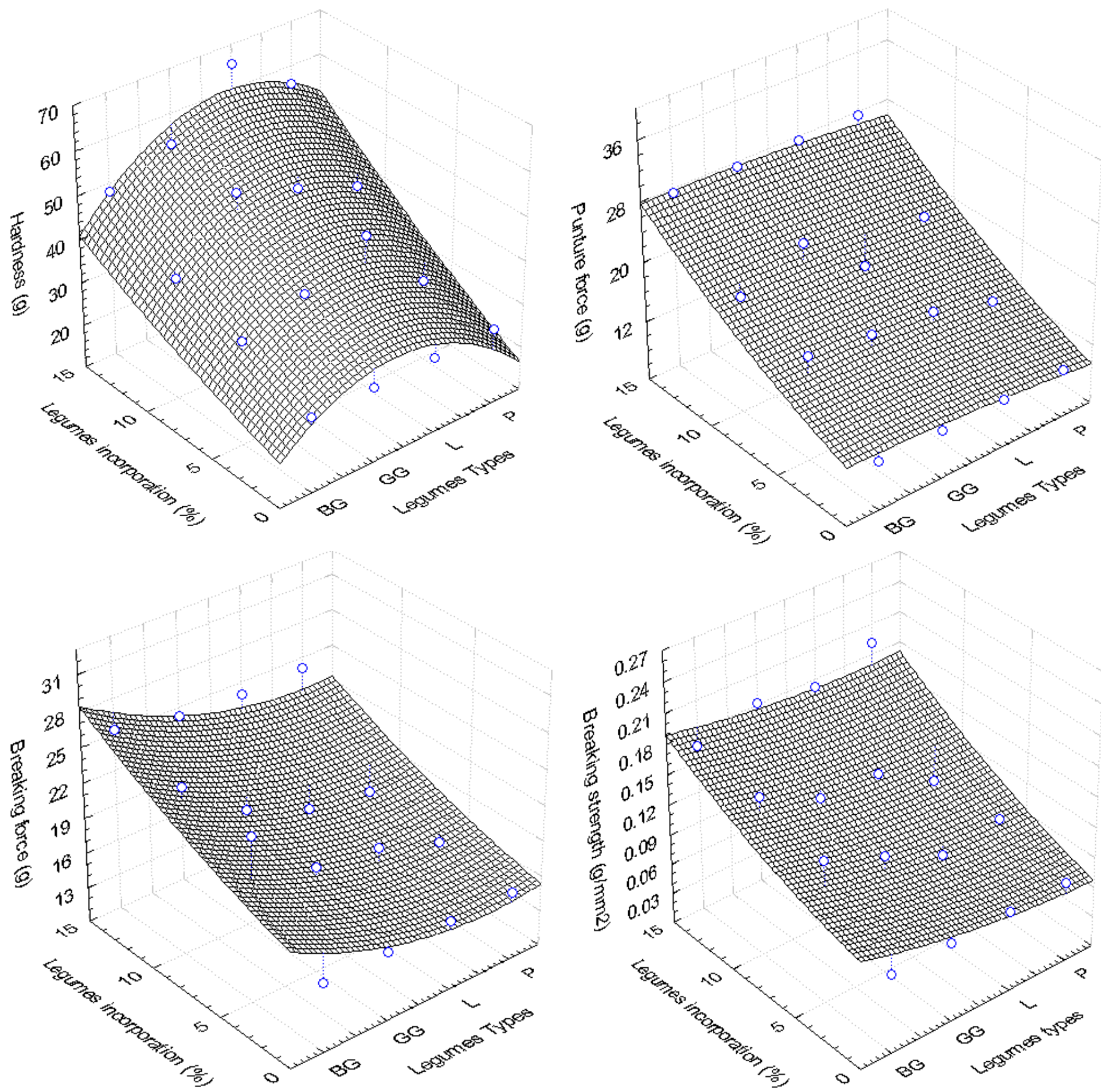

Fig. 2. Textural properties of dehulled legumes viz., black gram (BG), green gram (GG), lentil (L) and peas (P) incorporated with rice grits.

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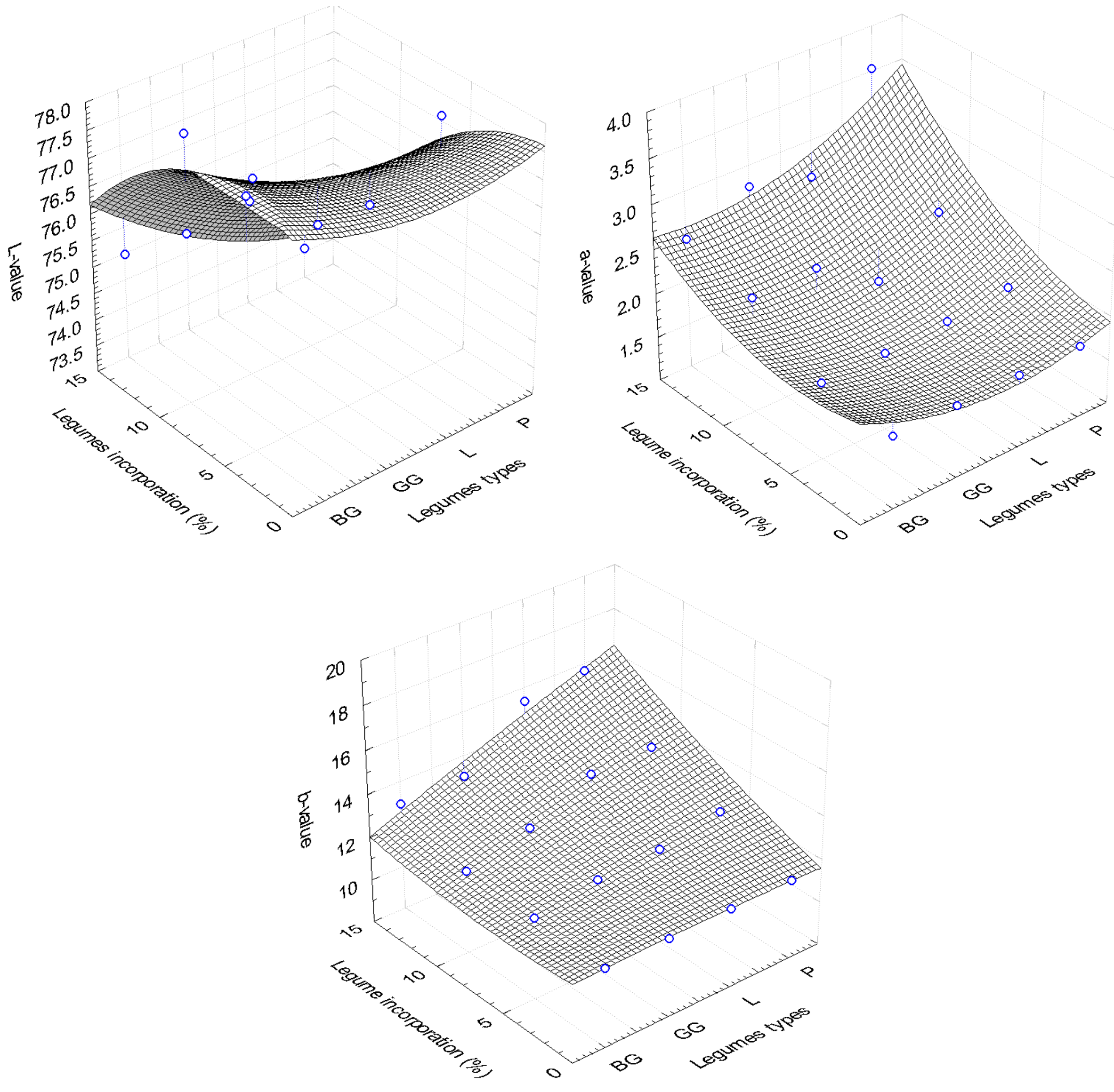

Fig. 3. Colour attributes of dehulled legumes viz., black gram (BG), green gram (GG), lentil (L) and peas (P) incorporated with rice grits.

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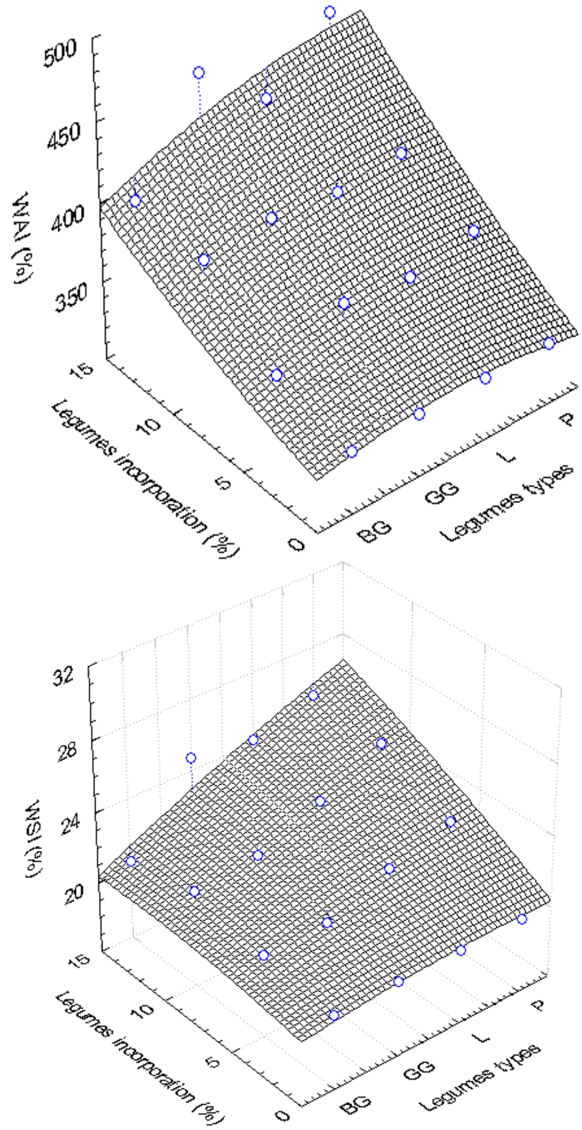

Fig. 4. Water absorption and water solubility indices of dehulled legumes viz., black gram (BG), green gram (GG), lentil (L) and peas (P) incorporated with rice grits.

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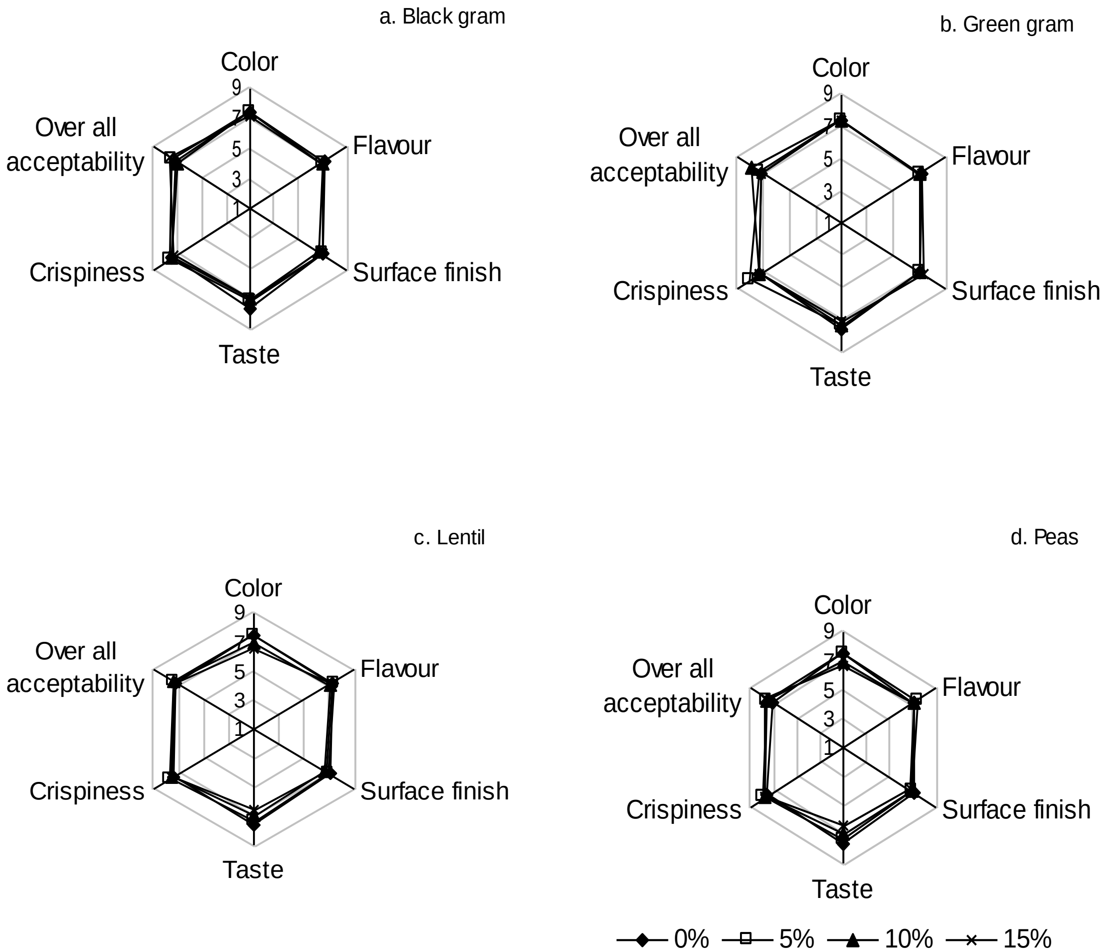

Fig. 5. Sensory scores of dehulled legumes viz., black gram, green gram, lentil, and peas based rice extrudates.