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Characterization of extruded products from millets-legumes in combinations

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Abstract
With Growing concern, there is a need to develop simpler technologies for the production of nutritious complementary foods. Therefore, in present investigation, total 12 combinations were prepared using pearlmillet and sorghum as base with addition of mungbean and chickpea. Samples were analyzed for functional and nutritional properties. Results revealed that TPC was more for PM blends; however antioxidant properties were similar for all. Addition of legumes improved the IVPD of the blends (63.74-80.61%). Bulk density was higher for the PM-blends and expansion ratio was more for S-blends. Therefore, as per sensory characteristics, S-legume snacks were found to be highly acceptable.

Keywords: Millets, legumes, extrusion, properties, sensory

1. Introduction

21st century challenges like climate fluctuations, upsurge of food prices due to increasing population, water scarcity, and additional socioeconomic impacts are expected to cause a great threat to food security worldwide, especially for the poorest people living in arid and sub-arid regions (Saleh *et al.*, 2013) [1].Absence of suitable processing technologies to prepare ready-to-use products has been the major limiting factors for their diversified food uses and better economic status (Jayabhaye *et al.*, 2014) [2]. An increasingly important determinant in food choice is the growing consumer concern about nutrition and health (Nehir and Simsek, 2012) [3]. Millets comprises of a good nutritional profile along with flavonoids and polyphenols, thus have high antioxidant activity (Chandrasekara *et al.*, 2012) [4].These pseudo cereals are gluten free and have low glycemic index, thus promotes health by managing diseases like type 2 diabetes and thus obesity and cardiovascular diseases (Kharat *et al.*, 2018) [5].
India is considered as the largest producer of many kinds of millets that are denoted as coarse cereals. Typical grain texture and hard seed coat of millets increases their keeping quality but makes them difficult to process as well as cook in convenient form. Generally development of nutritious complementary foods is a costly matter, so, there is a need to develop simpler technologies for the production of complementary foods that could be available to the poor section of the society as well (Devi *et al.*, 2014) [6]. Developing millet based low cost weaning foods for the poorer sections of our society to meet nutritional needs of the infants/children), should be accorded an extremely high priority.
Extrusion is one such method, through which low cost nutritious food products could be produced. Extruders offer various advantages like lower operating costs, higher productivity along with presenting versatility and energy efficiency (Thilagavathi *et al.*, 2015) [7]. Using extrusion, anti-nutritional factors of a raw material could also be minimized, thus increasing the consuming acceptability and leaving the product safe microbiologically (Nibedita and Sukumar, 2003) [8].
Pearl millet is one of the very few types of millet that contain more than 10% protein, but its protein is deficient in lysine. Besides, in this case, extrusion cooking offers additional benefits; namely, inactivation of lipases and enhancing the shelf-life of its products (Kaced *et al.*, 1984) [9].
Sorghum is an important crop grown in Asia, America and Africa, belongs to family Poaceae and is a good source of starch and protein Kafirin (Dayakar *et al.*, 2017) [10]. However, Millets lack in good quality protein, so combining them with soy/pulse or milk protein would enhance both quantity and quality of protein in millet products. Such a product if developed using

extrusion technology, would be low in fat, high in protein and fiber, rich in other functional aspects (Devi *et al.*, 2014) [6].

So a good quality snack is the one with the right raw materials in a right amount with a good amount of nutritious value. Therefore, the present investigation deals with the comparison of extrusion characteristics of pearl millet and sorghum as a base of complementary snacks with addition of legumes ie. mungbean and chickpea in order to improve the protein quality.

2. Material and methods

2.1 Raw materials: The raw materials used for product development such as pearlmillet, sorghum, mungbean and chickpea were procured from Directorate of Seed, Punjab Agricultural University, Ludhiana.

2.2. Milling of the raw materials; The grains were cleaned to remove any foreign material. The procured whole grains were milled to flour in a lab model mill.

2.3. Preparation of formulations; Formulations are depicted in Table 1.

2.4. Extrusion Conditions*;* Extrusion was performed on a co-rotating intermeshing twin screw extruder (Clextral, Firminy, France) (Fig 1.). The barrel diameter and its length to diameter ratio (L/D) was 25 mm and 16:1, respectively. The extruder barrel is divided into four zones. Temperature of the first, second, third and fourth zone was maintained at 40ºC, 70ºC and 100ºC, respectively, throughout the experiment.

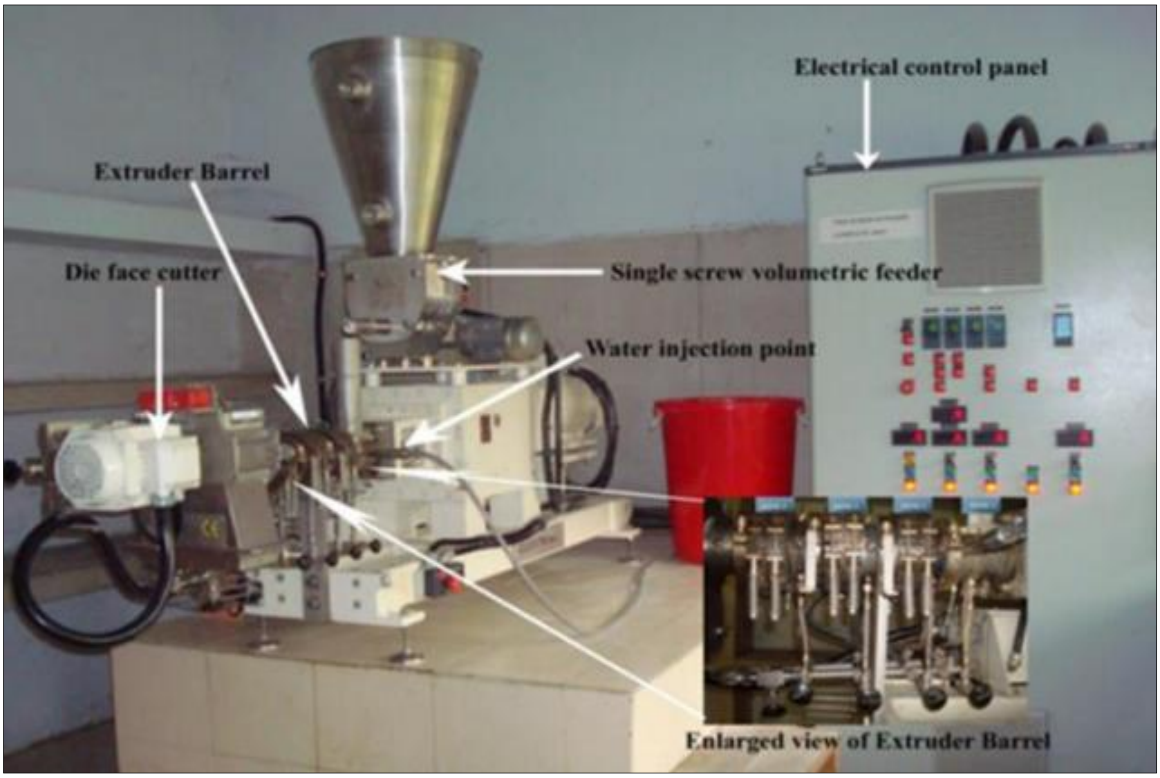

Fig 1: Co-rotating intermeshing twin screw extruder

2.5. Bulk density (BD); BD was measured by rapeseed displacement according to a method by Patil and coworkers (Patil *et al.*, 2007) [11].

2.6. Expansion ratio (ER); ER was calculated using a method by Kharat and coworkers [5]. The diameter of die used was 3mm.

2.7. Water Absorption Index (WAI) and water solubility Index (WSI)

WAI and WSI were measured according to method by Anderson and coworkers [12]. Results were calculated as mean of three readings.

2.8. Swelling Power (SP); swelling power was calculated according to method by Tester & Morrison [13].

2.9. Extraction of phenolic compounds; 2g ground extruded sample was extracted with 40ml acidified methanol (few drops of Hydrochloric acid added to 99.9% pure methanol). Sample was taken in a 100ml conical flask and 40ml acidified methanol was added to it. Flasks were placed on a hot plate by keeping the condenser over the flask. Keep the temperature low and let the boiling commence. As the samples start to boil, remove the flasks from the hot plate. Let the flasks cool. Repeat this for 2-3 times. The mixture was centrifuged (bench top) at 3000rpm for 20mins. The supernatant was used for determination of total phenolic content.

2.10. Total phenolic content (TPC); TPC was determined as per Folin Ciocalteu spectrophotometric method mentioned by Singleton and coworkers[14].The results were expressed as mg of gallic acid equivalents (mg GAE/g dry sample).

2.11. Antioxidant activity (AA); Antioxidant activity was analyzed according to the method by Singh and co-workers [15].

2.12. *In vitro* protein digestibility (IVPD); *In vitro* protein digestibility was analyzed according to the method by Singh and co-workers [15].

1.13. Color Analysis; Color of the extruded samples was measured using Hunter calorimeter. It represents the color in L*, a* and b* values, where "L*" represents the degree of lightness to darkness of the sample, "a*" represents redness to greenness whereas "b*" indicates yellowness to blueness on the hunter scale. The apparatus was first calibrated with the standard white and black tiles.

1.14. Sensory evaluation; The sensory assessments were conducted in Extrusion Lab, Department of Food Science & Technology. The panel of 20 members consisted of staff and students of the department, Punjab Agricultural University, Ludhiana. The panelists were naive to research objectives. Samples were coded randomly and served with the order of presentation counter-balanced. Panelists were provided with a glass of water and instructed to rinse and swallow water after testing every sample. Panelists are evaluated all samples based on its the based for acceptability based on its flavor, texture, taste, color and overall acceptability using nine-point hedonic scale (1 = dislike very much to 9 = like very much).

3. Results and discussion

3.1. Bulk density and Expansion ratio; The results revealed that pearlmillet based samples showed significantly higher bulk density as compared to sorghum-based samples. Whereas expansion ratio was significantly higher in case of sorghum-based samples. The highest bulk density was seen in PCh3 (0.240) followed by that of PCh2 (0.23). The results of other samples could be seen in Table 1. The higher BD levels may be due to higher crude fiber content that promotes high nucleation at die exit (Kharat *et al.*, 2018) [5]. Similar types of results were observed by Deshpande and co-workers[16]. Bulk density is considered to have inverse relationship with expansion ratio, which gives the degree of puffing of an extrudate (Filli *et al.*, 2012) [17]. It has already been reported that the pearlmillet based extrudates show a lower amount of expansion as well as sensory scores, thus a dense and hard texture (Yadav *et al.*, 2014) [18]. Whereas Khatak stated that extruded products from whole pearlmillet show a higher bulk density as compared to when additional ingredients such as corn flour are added (Khatak, 2014) [19]. Higher protein also affects expansion through their ability to distribute water in the matrix and their macro molecular structure.

3.2. Water absorption Index and Water solubility Index; It has been displayed in the results that sample SM1 gives highest WAI (5.290g/g) and SM3 had lowest value (3.68g/g). If we compare the results of PM and sorghum blends, WAI values did not have any significant difference. Increase in WAI may results from swelling of starch, uncovering of hydrophilic groups in starch–protein material due to extrusion, which ultimately results in greater availability and easier penetration of structures by water molecules. Similar results were reported by Dayakar and coworkers[10], where sorghum based extrudates exhibited WAI in range of 4.6-6.1g/g.

Whereas, the results have shown a significant difference in WSI of that sorghum blends as compared to the PM blends. Whereas, among sorghum blends sample SM3 exhibited highest WSI (38%) (Table 1). The results were in accordance to Sharmila and Athmaselvi, where millet and legume based extrudates displayed WSI in the range 20-50%[20]. Similar results were reported by Balasubramanian and coworkers, where an increase in WSI was seen with incorporation of legume proteins (Balasubramanian *et al.*, 2012) [21].

3.3. Swelling Power (SP); The Results have shown that the swelling power of PM based and sorghum-based samples differed significantly. SP was more in case of PM blends as compared to sorghum blends. If we compare among the pearl millet blends, highest SP was seen in PCh3 (4.48g/g). In case of sorghum blends, SM1 (3.67g/g) had highest SP. Among all the samples, lowest SP was exhibited by SM3 (1.88g/g) (Table 1).

Table 1: Physico-chemical properties of different formulations

	Bulk density (g/ml)	WAI (g/g)	WSI (%)	Swelling power (%)	Expansion ratio
PM1 (90% PM+10% M)	0.072 ± 0.003^{dC}	4.33 ± 0.01^{bA}	33.30 ± 0.36^{dA}	2.48 ± 0.02^{gE}	0.83 ± 0.001^{eA}
PM2 (80% PM+ 20% M)	0.162 ± 0.004^{bB}	4.10 ± 0.01^{dC}	27.06 ± 0.20^{eB}	3.60 ± 0.004^{dC}	0.81 ± 0.001^{gB}
PM3 (70% PM +30% M)	0.138 ± 0.004^{cB}	4.16 ± 0.01^{cB}	25.96 ± 0.15^{fC}	3.43 ± 0.01^{eD}	0.56 ± 0.002^{iC}
PCh1(90% PM +10% Ch)	0.172 ± 0.004^{bB}	4.33 ± 0.02^{bA}	20.23 ± 0.25^{gD}	3.97 ± 0.008^{bB}	0.46 ± 0.001^{jD}
PCh2 (80% PM+ 20% Ch)	0.230 ± 0.026^{aA}	4.18 ± 0.01^{cB}	16.04 ± 0.05^{jF}	2.35 ± 0.004^{hF}	0.03 ± 0.005^{kE}
PCh3 (70% PM+ 30% Ch)	0.240 ± 0.020^{aA}	4.01 ± 0.01^{eD}	18.05 ± 0.13^{iE}	4.48 ± 0.006^{aA}	0.02 ± 0.005^{lF}
SM1(90% S +10% M)	0.095 ± 0.004^{dP}	5.30 ± 0.04^{aP}	19.01 ± 0.01^{hT}	3.67 ± 0.01^{cP}	0.81 ± 0.001^{fT}
SM2 (80% S +20% M)	0.091 ± 0.004^{dP}	4.08 ± 0.03^{dQ}	35.99 ± 0.02^{bQ}	2.34 ± 0.004^{hS}	0.87 ± 0.001^{dS}
SM3 (70% S+30% M)	0.091 ± 0.002^{dQ}	3.66 ± 0.01^{gS}	38.02 ± 0.03^{aP}	1.88 ± 0.004^{iT}	0.92 ± 0.005^{bQ}
SCh1(90%S +10% Ch)	0.083 ± 0.003^{dP}	4.10 ± 0.01^{dQ}	35.00 ± 0.05^{cR}	2.50 ± 0.006^{gR}	0.90 ± 0.005^{cR}
SCh2(80% S +20% Ch)	0.097 ± 0.002^{dP}	4.12 ± 0.02^{dQ}	33.00 ± 0.12^{dS}	2.48 ± 0.005^{gS}	0.92 ± 0.005^{aP}
SCh3(70% S+ 30% Ch)	0.083 ± 0.003^{dQ}	3.88 ± 0.01^{fR}	36.06 ± 0.05^{bQ}	2.55 ± 0.003^{fQ}	0.80 ± 0.005^{hU}

Significance at 1% level, n=3, P<0.05

(PM-Pearl millet, S- Sorghum, M- Mungbean, Ch - Chickpea). (Where a, b, c to j superscripts represents the significant differences among all the samples. A, B to F superscripts represents significant difference among pearl millet blends. P, Q to U superscripts indicates significant differences among sorghum blends)

3.4. Color Analysis; L*-value was more for sample SM3 (52.77), a* value was highest for PCh3 (1.81) whereas b* value was found to be highest for SM3 (9.6). Color values for all the samples could be seen in Figure 2. As L value represents the lightness and darkness of the color and it has already been reported that Lower L-value represents the formation of brown pigments due to the heat application that leads to reactions (Sharmila and Athmaselvi, 2017) [20]. The color values of sorghum blends were having higher b* value ie more yellow color and lower a* values that gives lower red color, whereas pearl millet blends gave lesser yellow color ie-lower b* value and a* values were similar to sorghum blends. In case of extrusion, these changes were related to the browning reactions due to caramelization and Maillard reaction (Sawant, 2015) [22].

3.5. *In vitro* protein Digestibility (IVPD); The results indicate that Sorghum blends exhibited higher IVPD being highest in SCh3 (80.61%) and lowest in SM1 (63.74%). Among pearl millet blends, highest IVPD was observed in PCh3 (78.91%) and lowest in PM1 (65.99%) (Table 2). Higher PD may be due to higher chickpea content, thus higher protein. The improvement in digestibility may be attributed to denaturation of protein, destruction of the trypsin inhibitor or reduction of tannins and phytic acid that are more vulnerable to enzyme action (Angulo *et al.*, 2008) [23]. Similar results were reported by Fapojuwo and coworkers, where protein digestibility of sorghum increased greatly on extrusion (Fapojuwo *et al.*, 1987) [24]. Results are in accordance to Hamaker and coworkers, where protein digestibility of porridge was higher for decorticated sorghum extruded product than prepared from raw decorticated flour (Hamaker *et al.*, 1994) [25].

Table 2: Total Phenolic, antioxidant and protein digestibility properties of formulations.

Samples	TPC (µg GAE/g)	Antioxidant Activity (%)	*In vitro* protein Digestibility (IVPD)
PM1	6996.10± 6.76^{aA}	21.30±0.02^{gC}	65.99±0.62^{iF}
PM2	6984.03± 5.46^{aA}	19.79±0.08^{iE}	69.43±0.11^{gD}
PM3	6159.23± 9.48^{bB}	18.09±0.05^{jF}	70.22±0.22^{fC}
PCh1	6999.96± 1.69^{aA}	29.12±0.13^{bA}	67.20±0.09^{hE}
PCh2	5343.00± 8.05^{dE}	20.22±0.02^{hD}	71.29±0.17^{bB}
PCh3	5489.86± 9.02^{dC}	27.45±0.11^{cB}	78.91±0.07^{aA}
SM1	3944.30±8.55^{iT}	13.67±0.04^{lU}	63.74±0.07^{jU}
SM2	4811.40±11.10^{fQ}	23.08±0.09^{fS}	70.23±0.03^{fS}
SM3	5117.23± 4.60^{eP}	25.32±0.04^{dQ}	73.82±0.06^{dR}
SCh1	4031.70± 11.03^{gR}	32.60±0.05^{aP}	69.26±0.13^{gT}
SCh2	4010.76± 4.57^{hS}	23.43±0.05^{eR}	75.45±0.14^{cQ}
SCh3	3683.36± 6.62^{jU}	17.68±0.08^{kT}	80.61±0.06^{aP}

Significance at 1% level, n=3, P<0.05

(Where a, b, c to j superscripts represents the significant differences among all the samples.A, B to F superscripts represents significant difference among pearl millet blends. P, Q to U superscripts indicates significant differences among sorghum blends)

3.6. Total Phenolic content (TPC); Among the phytochemicals, total phenolic content mostly decreases during extrusion because of harsh environment. Contrarily some studies have also indicated increase during extrusion due to some reactions between the subunits of bioactive compounds (Wani and Kumari, 2016) [26]. Results in this study revealed that higher TPC was seen in case of PM blends as compared to sorghum ones. Among pearl millet blends, PM1 and PCh1 exhibited highest TPC of 6996.10 µg/gm whereas lowest was seen in PCh2 (5343.0 µg/gm) (Table 2). Among sorghum blends highest TPC was analyzed in case of SM3 (5117.23 µg/gm) and lowest for SM1 (3944.30 µg/gm). Similar results were reported in the study by Patil and coworkers (Patil *et al.*, 2016) [27].

3.7. Antioxidant activity (AA); Some studies have stated a decrease in antioxidant activity during extrusion (Gujral *et al.*, 2012) [28], Whereas some have reported increase in this area, which might be due to the formation of darker pigments at higher temperature, known for antioxidant properties (Xu and Chang, 2008) [29]. Overall the results have displayed that there wasn't a significant difference in the AA of sorghum and pearl millet based blends. It has been revealed that sorghum blends exhibited higher AA as compared to pearl millet blends, where highest AA was observed in case of SCh1(32.59%) and lowest for SM1 (13.62%). Among PM blends highest AA was seen in PCh1 (29.17%) (Table 2). Similar results were presented by Anunciacoa and fellow workers, where breakfast cereal prepared by using whole sorghum flour showed higher antioxidant activity as compared to whole wheat flour (Anunciacao *et al.*, 2017) [30].

3.8. Sensory Evaluation; Evaluation was carried out among different age groups ranging from 20 years to 60 years. Four to five people were carefully selected in the age groups of 20-30; 30-40; 40-50; 50-60 years. Evaluation of organoleptic characteristics of the extrudates such as appearance, color, taste, flavor, texture and overall acceptability were done with 9-point hedonic scale. The mean scores of sensory evaluation showed that all the extruded products prepared from composite flours were within the acceptable range. The overall acceptability (OA) scores for all the samples have been given in Figure 3 and the images of the products can be seen in Figure 2. According to OA scores, clearly sorghum blends were acceptable to the panel and if we specifically, the samples SM3 and SCh2 were highly acceptable.

PM1 PM2 PM3

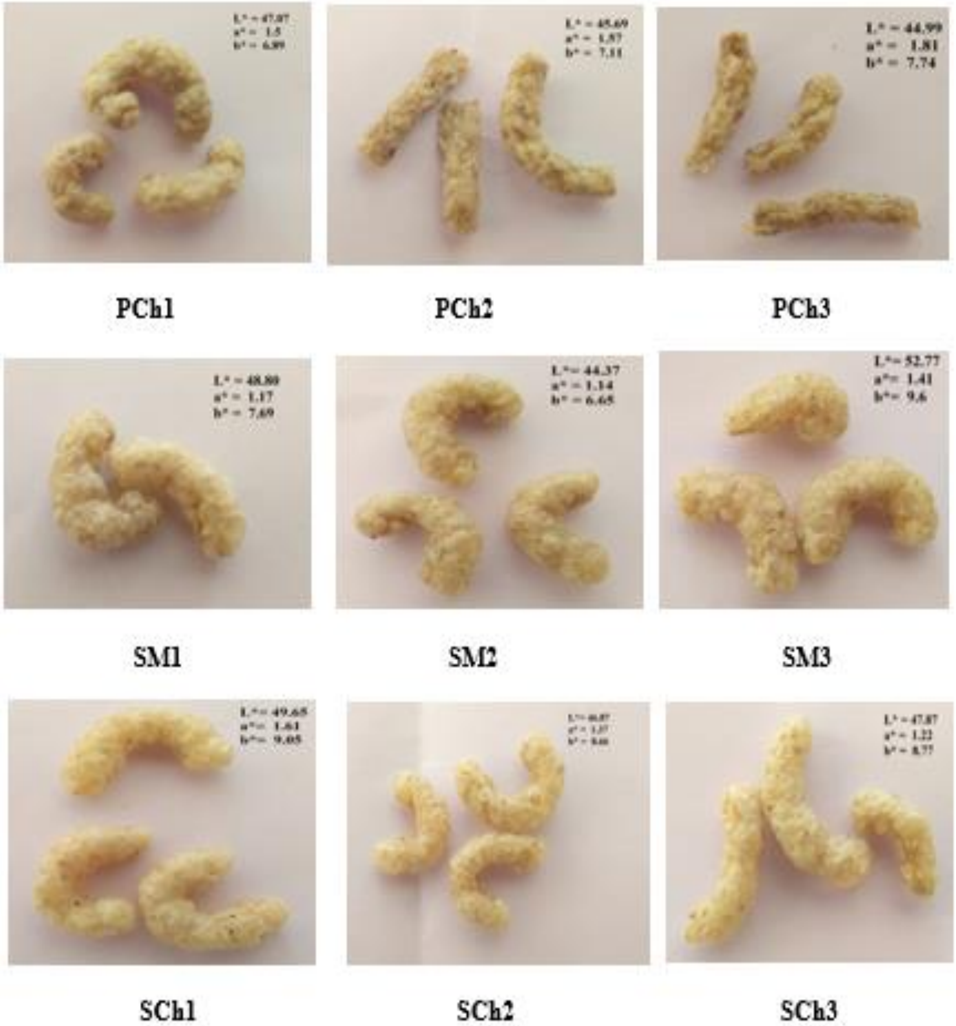

Fig 2: Images as well as the color analysis of the products.

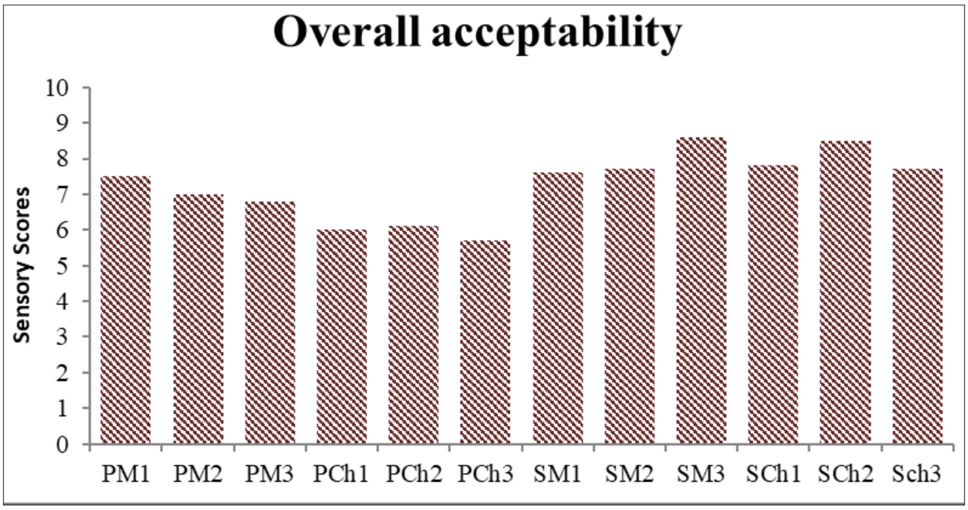

Fig 3: Sensory Scores of respective samples.

Conclusion

Results revealed that out of pearl-millet and sorghum, sorghum gave better results on the basis of properties necessary for an extrudate. Among sorghum samples, two samples (SM3 and SCh2) were found to be more acceptable and were selected for further analysis. Addition of legumes does improve the protein quality of the extrudates. Hence it could be concluded that extrusion is an efficient method to prepare millet-legume based ready to eat food products with high nutritious value and functional properties.

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