Qualitative Evaluation of Germinated Multi-Millet-Based Functional Snack Product

Abstract

Considering the health benefits of extrusion of germinated multi-millet grains can lead to the development of nutritionally important expanded snack products. Hence, the current study emphasizes extrusion processing to formulate made from multi-millet grains blends (Sorghum millet, Finger millet, Foxtail millet, Pearl millet) and Rice. The formulated blends are made in various ratios of 11.5:11.5:11.5:11.5:6:4 to produce better qualities of the extruded products. Although the effect of extrusion processing using a single extruder was adjusted for all multi millets grain preparation under the controlled moisture content of 20–21% (w.b), at the most stable die (with 3mm diameter) temperature of 130°C. However, keeping the constant screw speed of extruders to 270 rpm is needed for efficient extrusion processing. Results showed that the best-studied extruded snack product was T3 over T1 and T2. The suitability of T3 over T1 and T2 is based on the physicochemical properties such as having a high expansion ratio, low bulk density, low hardness, low moisture content, and water absorption index with the highest value recommended for all the ingredients, while water solubility index showed a negative correlation. The developed extruded snack quality products were obtained from T3 extruded sample which has the highest overall acceptable sensory properties.

Keywords millets, extrusion, functional snacks, multigrain, blends

1. Introduction

Germinated multi-millet grains with Extrusion cooking have been developed widely for the continuous processing of nutritional-enriched food products development. During extrusion processing, the raw feed material is exposed to high thermal and shear, and frictional energies to transform it into modified intermediate and finished products (Ilo et al. 1996). This extrusion cooking processing is conducted at high-temperature for an abbreviated time duration that prevents the essential temperature-sensitive nutrients from degradation. Ready-made food product includes majorly snacks prepared from high starch-holding cereal grain like rice as a primary feed material. Rice with high starch inclusion in multi-millet grains supplies a high expansion ratio to the composite foodstuff. Rice (*Orzya sativum)* form of 64.3% carbohydrates, 7.37% protein, 2.2% fat, 1.4% ash, and 0.8% fiber (Sawant et al. 2013). Millet and Rice-based extruded snacks products development is beneficial in the sense of having good nutraceutical properties and soften texture; however, their composite mixture sufficient to fulfill the requirement of other nutrients like proteins and other vital nutrients. Snack consumption contributes an important nutrient and calorie intake therefore their increased consumption in the foodstuffs market.

Millets are nutria-cereals grains obtained from different sources like sorghum (*Sorghum bicolor L.*) and available as pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine carocana*), kodo millet (*Paspalum scrobiculatum*), foxtail millet (*Setaria italica*), teff (*Eragrostis tef*), proso millet (*Panicum miliaceum*), little millet (*Panicum sumatrense*) and fonio (*Digitaris exilis*) (Rao et al. 2017) become a good source of nutrition in India. Although India dominates the global production of millets with a total share of about 41.0% and an estimated production of about 11.7 million tonnes during 2020–2021 (Ashoka et al. 2020). Although India ranks first among millet production and second in rice and pulses across the globe, despite this India ranks top among child malnutrition countries and consider a hub of other metabolic disorders like diabetes and overweighed incidences.

In recent year's development of composite extruded puffs of cereal grains has become a solution to malnutrition and enhanced the food security of developing countries like India. Incorporation of such high quality and nutritionally important cereals grains in the formulation while processing through extrusion could result in the development of nutritionally rich product snacks. It has been reported that composite rice and millet combined to raise the nutritive value of foodstuffs to a several folds because both are good sources of dietary fibers, easily digestible starch, and essential amino acids, especially Sulphur containing amino acids like methionine and cysteine, and have an abundant source of fatty acids as well (Nithiyanantham et al. 2019; Anitha, et al. 2020). In addition, it supplies vital minerals like calcium, phosphorous, magnesium, manganese, potassium, and iron (Annor et al. 2019) and act as a good source of vitamins like vitamin E and vitamin-B complex and overcome the deleterious effect of harmful disorder like cancer on human health. Considering these health benefits, the extrusion of rice and millet can be an effective way to produce nutritionally rich expanded snacks with higher consumer acceptability. In this context, very few studies have been conducted on the combination of extrusion and blending of two different fermented rice for the development of snacks with good sensory acceptability as studied by Rani et al. (2018). However, still, there has been no study on the evaluation of extrusion operating parameters on the physicochemical properties of puffed snacks prepared from a composite mixture of rice and millet. Hence, the current research work purpose was to examine the effect of extrusion processing conditions on the physicochemical properties of the developed snack products from germinated multi millets grains and further perfect the extrusion process.

2. Materials and methods

Raw material procurement and sample preparation

The raw materials like multi-millets namely Pearl millet, Finger millet, Sorghum millet, Foxtail millet, and the base was rice were obtained from the local market Meerut and evaluated at Food and drugs laboratory, situated at Meerut, Uttar Pradesh.

2.1 Germinated multi-millets grains preparation

The Sorghum millet, Finger millet, Foxtail millet, Pearl millet, and Rice grains were chosen for blends preparation and mixed in different ratios of 11.5:11.5:11.5:11.5:6:4. The blended samples were conditioned to a moisture content of 20–21% (w.b) by spraying with a calculated amount of water-salt mixture and then mixed thoroughly. The moisture content of each sample was determined by the hot air oven method (AOAC, 2005).

2.2 Extrusion cooking

Feeding of the pre-conditioned germinated multi-millets grains was conducted by using a single feeder Zigmo Agro Pvt. Ltd. The first experimental temperature was reached within 30 min and samples were poured into a feed hopper at the constant feed rate of 4 kg/h for easy and non-choking operation. The temperatures of two parallel barrel zones of the extruder from the feeder end were adjusted to 160 and 180°C, respectively. Each sample was collected at the most stable die (with 3mm diameter) temperature of 130°C. However, keeping the constant screw speed of extruders to 270rpm and moisture content to 25% while processing in a feeder. Three replicate samples T1, T2 and T3 were extruded for the standardized formulation of composite multi-millets grains.

Table 1 Standardization of formulation of composite multi-millets grains samples

Raw materials	Composite multi-millets grains samples		
	T1	**T2**	**T3**
Sorghum millet	11.5	11.5	11.5
Finger millet	11.5	11.5	11.5
Foxtail millet	11.5	11.5	11.5
Pearl millet	11.5	11.5	11.5
Rice	6	4	4
Salt (gm)	2	2	2
Water (ml)	115	115	115

Note. Values stand for the mean of triplicate ± standard deviation. Means with no common letters within a row differed ($p \leq 0.05$). T1- a ratio of preparation raw materials of multi-millets, T2- - a ratio of preparation raw materials of multi-millets, T3- - a ratio of preparation raw materials of multi-millets.

2.3 Extruded product qualitative analysis

2.3.1 Expansion ratio

This is the important functional parameter of the extruded product. It stands for the ratio of the extruder diameter to the die diameter and is also interrelated to the water solubility, hardness, water absorption, and crispness. Equation (1) represents the expansion ratio as given below:

$$\text{ER} = \frac{\text{De (Extruder diameter)}}{\text{Dd (Die diameter)}} \quad (1)$$

The diameter of the extruded product was measured randomly at distinct positions of the extrudates *via* using a digital vernier caliper (Rathod and Annapure 2017).

2.3.2 Bulk density

Extrude bulk density (BD) was figured out by calibrating according to the actual dimension of the extruder and its mass (m). The calibrated value of density was measured as per the length, diameter, and dimension of the piece of extruder (assuming the extruded matter is cylindrical) (Rathod and Annapure 2017).

Equation (2) represents the bulk density:

$$\text{BD} = \frac{4\times \text{m}}{\pi \text{D}_\text{e}^2 \times \text{L}} \qquad (2)$$

Were, BD: bulk density (Kg/cm^3) of the extrudate; m: mass of the extrudate (Kg); De: diameter of the extrudate (E); L: length of the extrudate (E). Extruder ten pieces were randomly selected to estimate the bulk density of each extruder and the average was taken.

2.3.3 Water absorption index (WAI) and water solubility index (WSI)

WAI and WSI parameters indicate the hydration properties of the extruded samples were measured according to the Kaur et al. (2014) method. Briefly, 2.5 g of ground dry sample was suspended in 25ml distilled water followed by constant stirring for 30min. Further, the solution was centrifuged at 8000 rpm for 15 min and further, separated and decant the supernatant and dried the sediment to determine its weight and the amount of solid content. The WAI (g/g) and WSI (%) were calibrated according to the following given Eqs. 3 and 4.

$$\text{WAI (g/g)} = \text{W}_{\text{news}/\text{W}_{\text{ds}}} \qquad (3)$$

$$\text{WSI (\%)} = \frac{\text{W solid, supernatant}}{\text{W dry, sample}} \qquad (4)$$

Where; W_{ws}= weight of wet sediment; W_{ds}= weight of dry sediment; $W_{Solid,\ supernatant}$: weight of solid in supernatant; $W_{dry\ sample}$: weight of the dry sample.

2.3.4 Texture analysis

The texture properties of the multi-millet puffed extrude were calibrated using a textural analyzer (Model: TA-XT2i; Brookfield Engineering Labs. Inc.). The Hardness of extrudes was measured based on the magnitude of compression force (N) using the compression probe of the texture analyzer. Breakage of an extruder with a 5kg load size was tested under 10.0mm/s pretest speed, 0.5mm/s of test speed, and post speed. The hardness of the millets-based extruder was measured as per the Sawant et al. (2013) standard protocol using the given equations (5).

$$\text{F}_{\text{cr}} = \frac{S}{d} \qquad (5)$$

Where; For compression force; S: area under curve (mm^2) and d: probe distance travelled

2.3.5 Moisture content analysis

The dried convention method was used to determine the moisture content of the samples every 15 days. A 5gm quantity of the cylindrical shape of the sample was measured accurately by following the Rani et al. 2018 method and calibrated according to the equation (6):

$$\text{Moisture content} = \frac{\text{final weight} - \text{initial weight}}{\text{sample weight}} \times 100 \quad (6)$$

2.3.6 Protein content estimation

Quantification of the extruded samples was measured using the spectral lab. semi-automatic titration analyzer by following the Kjeldahl method (AOAC, 1990). The percentage of nitrogen present in the sample was estimated to calculate the exact amount of protein present in the sample as per the given formula (7):

$$(\%)\ N_2 \times 6.25\ \text{factor} \quad (7)$$

2.3.7 Evaluation of sensory attributes

The assessment of sensory attributes of the developed product was conducted at a Regional public analytical laboratory. The developed product with an added flavor of Maggie masala and dried coated with commercial chat masala was served to a 16-member panel of judges for testing purposes. Judges tested the overall acceptability of developed products as per taste, texture, color, flavor, and appearance and mark them according to the 5-point standard scale (1-poor, 2-fair, 3-good, 4-very good, 5-excellent) Fadlallah et al. (2010). The set of results was obtained by the fuzzy logic approach as observed in Das's (2005) and Debjani et al. (2013) report.

Collection of Raw materials
⇩
Cleaning
⇩
Soaking (Cold water for 1 day at 5-8°C)
⇩
Half – Parobiling
⇩
Drying (sun drying)
⇩
Dehusking
⇩
Batch Mixture (Mix all raw ingredients with water and salt)
⇩
Extrusion Cooking (Single Extruder)
⇩
Flavoring/Seasoning of puff (Magic Masala)
⇩
Cooling conveyor (cool down puffed)
⇩
Snacks product formulation
⇩
Qualitative analysis of extruded product

Fig 1. Flow chart of snack products formulation from multi-millet extruded puffs

2.3.8 Statistical analysis

All the experimental analyses were performed in a triplicate manner and mean values are presented with respective standard deviations. Considered variables were found significant at $p<0.001$ level using the Graph-pad software vers.2.0.

3. Results and Discussion

3.1 Expansion ratio

Expansion is one of the most important parameters which are controlled through the physical variables while processing extrudes in a feeder. The observed results of the expansion ratio (ER) of extrudes indicate that the T1 (4.22±0.01) has found more decrement as compared to the T2 and T3 samples. The possible reason behind the decrement in the expansion ratio as in the case of T1-composite flour may be due to the increment in dietary fibers and decrease in the protein amount while more expansion ratio was observed in T2 (4.45±0.04) and T3 (4.33±0.033) made composite flour. A significant increment in the expansion ratio was also reported by Shannon et al. (2010) as described in the current study.

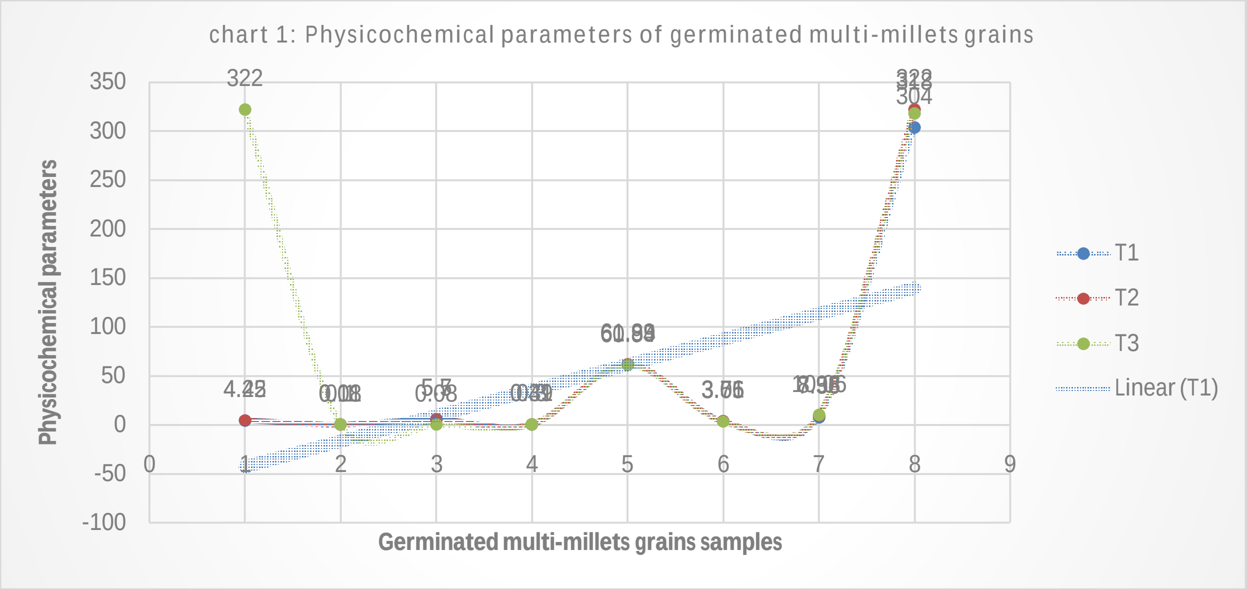
3.2 Bulk density

The bulk density of evaluated extrudes samples (T1 and T2) almost remain the same but the T3 sample show (0.08±0.071) higher bulk density. T3 higher bulk density might be due to the existence of more crude fiber in the germinated multi-millet puffs. From table 2, it can be concluded that density was significantly affected by temperature interaction with die diameter and screw speed $p<0.001$. This density increment might result in a sudden pressure drop in a lesser residence time creating highly expanded extrudes formation takes place. A similar trend of decrease in bulk density with temperature rise was also observed by Kaur et al. (2014); Ojokoh et al. (2015).

Table 2 Physicochemical parameters of germinated multi-millets grains

Physicochemical parameters	Germinated multi-millets grains samples		
	T1	**T2**	**T3**
Expansion ratio	4.22±0.01	4.45±0.04	4.33±0.033
Bulk density (Kg/cm^3)	0.11±0.028	0.10±0.050	0.08±0.071
Water absorption index (gm/gm)	5.7±0.048	5.5±0.08	5.1±0.058
Water solubility index (%)	0.30±0.025	0.41±0.046	0.39±0.077
Hardness (N)	61.35±2.16	61.89±1.71	60.94±2.86
Moisture content (% dB.)	3.71±0.022	3.56±0.061	3.05±0.02
Protein content (g/100g)	7.56±0.66	8.98±0.78	10.06±0.96
Water holding capacity	304±0.011	322±0.023	318±0.068

Note. Values stand for the mean of triplicate ± standard deviation. Means with no common letters within a row differed ($p \leq 0.05$). T1- the ratio of preparation raw materials of multi-millets, T2- - the ratio of preparation raw materials of multi-millets, T3- - the ratio of preparation raw materials of multi-millets.



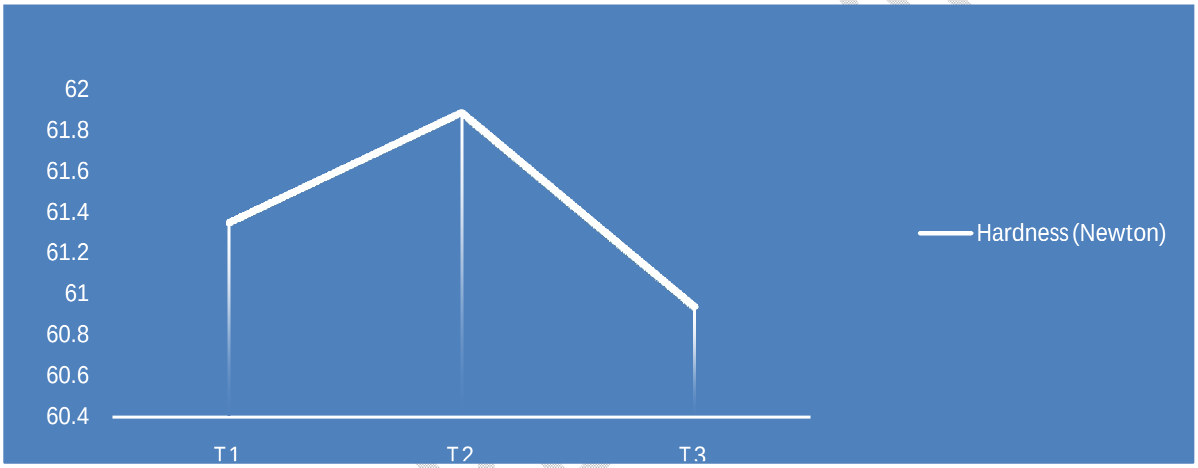
Note. Values stand for a mean of triplicate ± standard deviation. Means with no common letters within a row differed ($p \leq 0.05$ T1- the ratio of preparation raw materials of multi-millets, T2- - a ratio of preparation raw materials of multi-millets, T3- - a ratio of preparation raw materials of multi-millets.

3.3 Water absorption index (WAI) and water solubility index (WSI)

The water solubility index was found greater in the case of T2 composite flour (0.41±0.046) followed by T3 made extruded sample (0.39±0.077) and the least water solubility index (0.30±0.025) was observed in T1 extruded sample. The water solubility index was increased when the rice is mixed in millet-based composite flour. While the water absorption index was found higher in the T1 (5.7±0.048) extruded sample followed by T2 (5.5±0.08) T2 composite flour than in T3 (5.1±0.058) composite flour. The water absorption index was increased as the barrel temperature is elevated to180°C from 160°C with an increment of screw speed. An increment in the water absorption index was noted in extruded products which might be attributed due to the product puffing, thereby; more imbibing of a greater amount of water into the matrix as reported by Roopa and Premavalli, (2008). For the products made out of a 3 mm diameter die opening, a rise in screw speed and temperature resulted in an increment of WSI. In addition, higher WSI is often related to the enhanced adhesiveness of extruded products, therefore, products with higher solubility are lesser chances of acceptability by consumers. The WAI and WSI values obtained in this study were found in agreement with those reported by Singh and Muthukumarappan, (2016).

3.4 Texture analysis

The hardness (N) of the millet-based extruded samples significantly varied from 61.89 to 60.94 as shown in table 1. Millet's addition in composite flour slightly raised the compression force strength of extruded samples in this order T2 and T1 as compared to T3. No momentous change in the hardness of extruded samples was noted with the increment in the temperature and screw speed. Similar kind of results was seen by Gat and Ananthanarayan, (2015). Further, it was observed in this study that higher temperature and increased screw speed contribute to an incremental effect on the hardness of extruded samples. It was presented in fig 2.



Note. Values stand for a mean of triplicate ± standard deviation. Means with no common letters within a row differed ($p \leq 0.05$ T1- the ratio of preparation raw materials of multi-millets, T2- - the ratio of preparation raw materials of multi-millets, T3- - a ratio of preparation raw materials of multi-millets.

Fig 2. The hardness of the extruded samples

3.5 Moisture content analysis

The moisture content of the extruded product was varied in the range of 3.05% dry mass basis (dB) to 3.71%db which is crucial for the stability of the developed product under the storage period. Moreover, the effect of barrel temperature and screw speed on moisture content (MC) of produced extrudes from the 3mm die has found no significant change in T1, T2, and T3 products. As presented in table 2. Seth et al. (2015) reported that the extruded product development was positively correlated with moisture content and yam flour while negatively correlated to the barrel temperature.

3.6 Protein digestibility estimation

The percent protein digestibility of multi-millet extruded products (T1, T2, and T3) varied from 86.9, 84.5, and 83.3 at lower to the higher temperature range in 130°C, 160°C, and 180°C. It was concluded from this data that the (%) protein digestibility decreased as the barrel temperature increased. The result of the current study was found consistent with the earlier investigated study by Ghumman et al. (2016). Further, the effect of extrusion temperature on millets made composite flour may degrade the proteins which affects the quality of extruded product formulation.

3.7 Sensory attributes evaluation

The sensory assessment of prepared extruded snacks was calibrated according to the significant average score value. The score values of extruded snack products (T1, T2, and T3) were obtained from the fuzzy logic approach. It indicated the higher overall acceptability of multi-millet-based composite flour snack products. T3 extruded product has more compatibility in terms of appearance (6.01±0.011), color (5.32±0.011), and but there is no significant change was observed in the flavor (5.14±0.021), texture (5.91±0.050), taste (5.76±0.039) and overall acceptability (5.70±0.031) of three developed products. Further, the developed extruded products were closely comparable to the control. The obtained results were found consistent with the reported Coutinho et al. (2013) results. All the sensory properties of extruded products were presented in table 3 and fig 3.

Table 3. Average score values of extruded products

Sensory attributes evaluation	Extruded Products		
	T1	**T2**	**T3**
Colour	5.10±0.02	5.47±0.021	5.32±0.011
Flavor	5.09±0.01	5.11±0.04	5.14±0.021
Texture	4.90±0.03	5.16±0.03	5.91±0.050
Taste	4.50±0.05	5.31±0.01	5.76±0.039
Appearance	4.68±0.03	4.68±0.03	6.01±0.011
Overall acceptability	5.30±0.04	5.15±0.04	5.70±0.031

Note. Values stand for a mean of triplicate ± standard deviation. Means with no common letters within a row differed ($p \leq 0.05$ T1- the ratio of preparation raw materials of multi-millets, T2- - the ratio of preparation raw materials of multi-millets, T3- - the ratio of preparation raw materials of multi-millets.

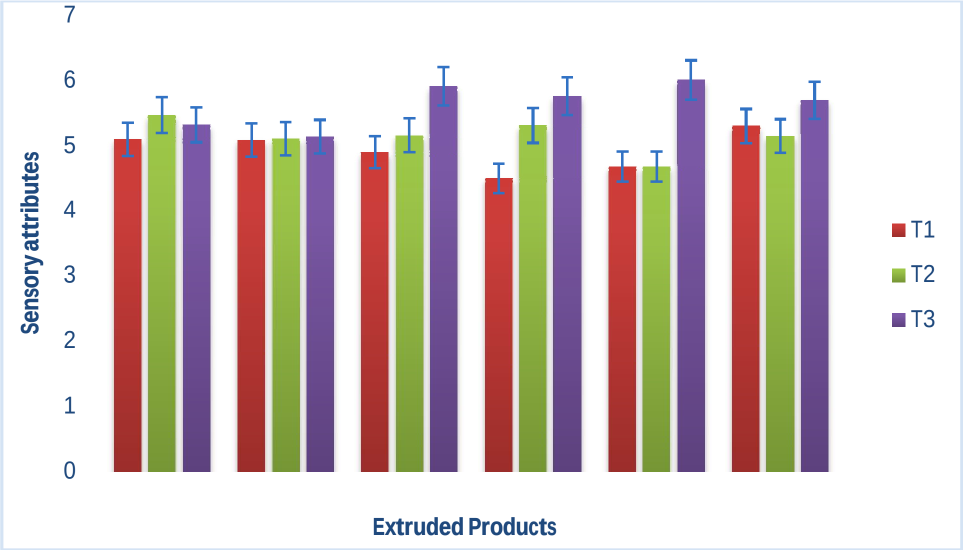


Fig 3. Sensory characteristics of developed extruded products

Note. Values stand for a mean of triplicate ± standard deviation. Means with no common letters within a row differed ($p \leq 0.05$ T1- the ratio of preparation raw materials of multi-millets, T2- - a ratio of preparation raw materials of multi-millets, T3- - a ratio of preparation raw materials of multi-millets.

4. Conclusion

The present study concluded that the germinated multi-millet grains were made from millet blends (Sorghum millet, Finger millet, Foxtail millet, Pearl millet) and Rice. The formulated grains blends are made in the ratio of 11.5:11.5:11.5:11.5:6:4 to produce better qualities of the extruded products. The studied physicochemical properties reflect the best-suited extruded snack products such as having a high expansion ratio, low bulk density, low hardness, low moisture content, and water absorption index with the highest value recommended for all the ingredients, whereas the water solubility index showed a negative correlation. The developed extruded product has overall acceptable sensory properties. Further, the use of low-value cereals with added nutrition to produce healthier and multi-nutritive snack food products open up a new dimension in the food industrial sector.

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