International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 2 Feb 2021, pp: 01-15 www.ijaem.net ISSN: 2395-5252

# A Study on Development of Extruded Products Incorporated With Millets

Sowjanya Lakkoju
*Student, university college of technology (A),OSMANIA UNIVERSITY,HYDERABAD, Telangana*

Submitted: 25-01-2021 Revised: 05-02-2021 Accepted: 10-02-2021

**ABSTRACT**: The smart foods are considered as underutilized sorghum and minor millets, i.e., whose potential is not fully exploited. In the case of minerals, fibre, vitamins especially B1 and B2 and energy, millets are superior as compared to major cereals, such as rice and wheat grain. A study was conducted with different proportions of composite flour blends of Sorghum, Finger millet, Barnyard millet and Bengal gram flour content in the blends were kept at constant and blending ratios of composite flours were finalized based on the most stable product expansion with constant moisture content. The extrusion cooking was carried out using a twin screw extruder at optimized extrusion parameters namely temperature: 115˚C and 90°C for two different heating zones, die diameter: 3 mm and screw speed: 400 rpm. In terms of physical properties extruded sample T1 (Sorghum: Finger Millet: Barnyad Millet: Chickpea in the ratios 50; 10; 10:30) has maximum expansion ratio (3.30) and lower bulk density (0.17g/ml) than other samples. The nutritional analysis showed higher nutrients content in sample T1 when compared to the control and other samples. The mean sensory values of overall acceptability for control, T1, T2 and T3 were found as 7.7 8.9, 8.5 and 7.7 respectively on the Hedonic scale. All the combinations of flours in composite extruded snacks valued in between like moderately to like very much. Highest score was observed in extruded sample T1, which was made from the blend of Sorghum: Finger Millet: Barnyad Millet: Chickpea (50:10:10:30).

**KEYWORDS:** Composite millet flour, Sorghum, Barnyard millet, Finger millet, Extrudates, Nutritional composition, Phenolic content, Antioxidant activity

## I. INTRODUCTION

Sorghum and millets crops are called Nutri-cereals or Smart Food because they fulfill the criteria of being good for individuals (nutrition and health), for the planet (environments) and for the farmer (nutrition, health and income). Smart Food is a global initiative that aims at diversifying staples (Seetha et al., 2019). The focus on nutri-cereals can lead to major climate nutri smart impacts with respect to alleviating malnutrition and ensuring better on-farm diversity. India is producing 42.9 million tonnes of nutri-cereals from an area of 24.81 million hectares (Directorate of Economics and Statistics of India 2019).The average carbohydrate content of millets and sorghum varies from 56.88 to 72.97 g/100 g, protein content from 7.5 to 12.5% and lipid content ranges between 1.3 and 6 g/100 g. They are also rich source crude fiber as well as dietary fiber and rich in vitamins and minerals (Poshadri et al., 2020) Sorghum ranks 5$^{th}$ most important cereal in the world after rice, wheat, maize and barley amongst the top important cereal crops in the world with its origin believed to be from Africa, Indian Ocean, Australia and the Pacific Ocean (FAO/WHO, 2007).

India is the leading producer of small millets namely, finger millet, kodo millet, foxtail millet, barnyard millet, proso millet and little millet. Currently India producing more than 2.0 million tonnes of Ragi and 0.5 million tones ofsmall millets (Directorate of Economics and statistics, India 2019). Annual planting area under them is around 2.5 million hectares; and nearly 1.5 million hectares is under finger millet comprising about 40-50% of crop's global area. Small millets form an important component of the traditional cropping systems and contribute significantly to the regional food and nutritional security and diversity in the national food basket. They are also important in areas of their production as dryland crops, as well as for hill agriculture. The small millet grains have longer storage life, and can be termed as famine reserve. The resilience exhibited by them may prove good for their adjustment to different eco-systems and make them potential crops for contingency plantings (Verma V and Patel S., 2013).

Barnyard (Echinochloa frumentacea) is one of the fastest growing crops of all the millets, mature in 90 to 100 days. They are an important source of vital minerals like niacin, magnesium, phosphorus, manganese, iron and potassium. They contain high amounts of protein, fiber, essential amino acid methionine, lecithin, and vitamin E (Shobana Devi R and Nazni, 2016). Recent studies have shown that due to the high content of these nutrients, millets have therapeutic benefits such as control of asthma, migraine, blood pressure, diabetes, heart disease, atherosclerosis and heart attack. Fibre, in millet, prevents gallstones formation. Because of these benefits, millets can be used in functional foods and as nutraceuticals. Hence, they are also called as 'nutri cereals' (Stanly J M and Shanmugam A., 2013). Ragi and Small millet have considerable further potential to be used as a human food and beverage source. In developing countries the commercial processing of these locally grown grains into value-added food and beverage products is an important driver for economic development (Taylor, 2004). In India, barnyard millet is extensively grown in the central part where it is known as sawa, shama, samu, shamula, kudiraivali, sanwa, etc. (Lohani and Pandey 2012). Its cultivation is mainly confined to tribal belts of Orissa, Maharashtra, Madhya Pradesh, Tamil Nadu, Telangana, Bihar, Punjab, Gujrat and the hills of Uttarakhand. It is one of the most popular minor cereal kharif crop of Uttarakhand and is grown under rainfed condition in the hills up to a height of 2,000 m. Often, it is grown as a border crop between other plantations (Kumar et al., 2000). The barnyard millet crop is harvested at 24–26% (dry basis, db) grain moisture content and harvested grains are dried to about 12% (db) moisture content (Singh et al. 2009). The barnyard millet contains low carbohydrate which are slowly digestible and a nature's gift for the modern mankind (Ugare, 2008). Similar to rice, the grain of barnyard millet is used as food and can be cooked. It can be used as a functional food for patients with allergic diseases, including atopic dermatitis (Watanabe,1999). Accordingly, its importance and demand as a functional crop in Korea and Japan are now increasing. It is an excellent source of dietary fibre with good amounts of soluble and insoluble fractions and fair source of highly digestible protein (Hadimani&Malleshi, 1993). For the production of most foods, the grains are decorticated using mortars and de-hullers. Dehulling is a process of removal of chaff or husk from the grain. Chaff or Husk is the inedible, dry, scaly protective casing of the seeds of cereal grain. It is either used as livestock fodder, or is a waste material ploughed into the soil or burnt. Over dehulling results in loss of endosperm and thereby loss of grain whereas under dehulling might leave some grains with husk which is again undesirable. So proper dehulling is desirable and essential for further processing. The barnyard millet contains 11.0% protein, 3.9% fat, 4.5% minerals and contains higher amount of fiber 13.6%.

Sorghum (Sorghum bicolor (L.) Moench is a gluten free cereal and is rich in dietary fiber, minerals and phenolic compounds (Dlamini et al., 2016). Its cultivation, demand and use have, however, been declining over time since there are no alternative uses. Sorghum grain is mainly consumed by households as a jowar roti or coarse porridge in rural India. In recent years the demand for sorghum grits has grown in the beer production industry as adjuncts (Olu Malomo et al., 2012). A variety of ready-to-eat value added snacks have been mainly prepared from wheat, corn and rice. Use of sorghum in snacks is one area that has not been adequately explored given that it is generally easier for most people to consume snack foods rather than other types of complementary foods.

Finger millet (Eleusine coracana (L.) Gaertn.) is the most important small millet in the tropics and contains high amount of calcium, iron and zinc (Anitha S et al., 2019). The grains are staple cereal food in some parts of Africa and India. In addition to micro- and macro-nutrients, it is also a good source of phytochemicals mainly phenolic compounds which assist in reducing chronic diseases like diabetes, cancer and cardiovascular diseases (Chandrasekara and Shahidi, 2011). Although a gluten free grain with low-glycemic index with nutritional and nutraceutical advantages, Finger Millet is neglected and underutilized (Amadou et al., 2013). Moreover, the more balanced amino acids available in finger millet complement the amino acids present in chickpea, thus creating a complete protein.

Chickpea (Cicer arietinum L.) is another legume, grown in tropical and subtropical areas, that presents high potential as a functional ingredient for the food industry. The chickpeas contain moderately high protein (17–22%), low fat (6.48%), high available carbohydrate (50%) and crude fiber contents of 3.82% dry basis (Saleh and Tarek, 2006). The available carbohydrate is mainly starch which is reported to be slow digestible, thus eliciting lowglycaemic responses in human nutrition. Hence chickpea seeds can play an important role as a low-glycaemic functional ingredient in a healthy diet (GamlathShirani and Ravindran Ganesharanee., 2009). India grows chickpea on about 7.0 million ha area producing 9.6 million tonnes which represents 30 per cent and 38 per cent of the national pulse acreage and production, respectively.

Extrusion cooking is an industrial cooking process that combines high pressure, heat and mechanical force in a short period of time, causing physical and chemical changes. Besides, extrusion has been used to create new products using blends and ingredients

that follow a continued growth of the food market (Tovar-Jiménez et al., 2015). Cooking-extrusion of starchy material has become a very used technique to obtain a wide range of products such as snacks, breakfast cereals, special flours (for instant soup mixes, porridge, etc.) (Bouzaza et al., 1996; Gonza´lez et al., 2000). The process consists of converting a non-cohesive granular material (grits and flour), composed of biopolymers (starch, proteins) into a re-structured solid in one operation. This thermo mechanical cooking involves the conversion of solid material in a viscoelastic fluid or ‘‘melt’’. That is, the transport mechanism through the extruder changes along the screw from solid flow to fluid flow. As a consequence of the pressure built up during fluid flow, high shear stresses are developed, which cause structural transformations in the material. These transformations include: loss of starch crystalline structure, destruction of granular structure, rupture of glycosidic bonds and new molecular interactions(Gonza´lez, Torres, & De Greef, 2002). Finally, as the melt comes out from the die, it expands as a consequence of the water flashing from liquid to vapor state. Such expansion will depend upon the melt viscoelastic properties (Arhaliass, Bouvier, and Legrand, 2003). The process of extrusion not only results in desirable properties like expansion as in case of ready to eat snack but it can also help in reducing toxicity. Aflatoxin produced by toxigenic strains of Aspergillus spp. in the infected grains was found to be reduced by extrusion cooking (Weidenborner, 2007).

In view of the health conscious demography, raising per capita income and increasing preference towards use of composite millet based food products by people, the present work was undertaken to develop nutri-cereals based ready-to-eat snacks. And hence the, present investigation is under taken with following distinct objectives as follows

- To optimize the formulation and process for production of RTE snack using extrusion cooking
- To evaluate the physical properties of extrudates
- To evaluate the nutritional properties of extrudates
- To evaluate sensory attribute of extruded snack
- To evaluate the techno-economic feasibility

## II. REVIEW OF LITERATURE

The review of literature is discussed pertaining to investigation on “A Study on development of extruded products incorporated with Millets” for production of Ready to Eat snacks with promising health benefits.

Momanyi et al., (2020) were formulated and analyzed the physical, nutritional and sensory attributes of baobab based ready-to-eat sorghum and cowpea blend snack bars. Popped sorghum, baked cowpeas and baobab pulp powder were blended in five different formulations (45:55:0; 50:45:5; 55:35:5; 55:35:10; 60:25:15; 65:15:20) to produce ready-to-eat (RTE) snack bars. The nutrient composition, physical properties and sensory qualities of the bars were ana- lyzed and significant difference between means determined by Tukey test, at $p < 0.05$. Crude protein in the formulations ranged between 11.38 ±0.35 g/100 g and 21.35 ±0.89 g/100 g), total fat content ranged between 2 ±0.03 and 3.26 ±0.13 while crude fiber ranged between 1.59 ±0.12 g/100 g and 2.76 ±0.02 g/100 g. The carbohydrate content of the RTE snack varied significantly between 61.1 ±3.32 g/100 g and 73.25 ±0.31 g/100 g while the energy content ranged between 1502.71 ±43.7 KJ and 1524.06 ±30.47 KJ. A significant increase in vitamin C concentration between 8.76 ±0.49 g/100 g and 21.16 ±2.03 g/100 g with increasing baobab content was observed. Iron concentration of the snack ranged between 4.34 ±1.80 g/100 g and 5.76 ±1.78 g/100 g while Zinc concentration (1.65 ±0.35 g/100 g and 2.76 ±0.14 g/100 g) was statistically different between the formulations. The sensory evaluation of the product revealed that color, taste, texture, aroma, appearance and overall quality were in acceptable range with mean scores of above 5. Generally, snack bars with low baobab concentration were the most preferred with RTEs3 being the most preferred. The readily available drought tolerant crops used in the formulation of the baobab snack bars can serve to diversify diets and increase the nutrient intake of household’s particularly, during food scarcity since it is an easy home to make snack. In addition, the snack having an acceptability score of 5, has a great market potential as a convenient food, as consumer needs are changing towards more convenient foods as well as less refined grains.

Davy et al., (2017) were blended the roasted coffee powder (CP) in whole grain sorghum flours of two genotypes and extruded in two water content conditions and the variations of total phenolic compounds (TP), phenolic acids and antioxidant capacity (AC) were investigated as well as the functional properties. Increasing CP and moisture lead to a reduction of expansion, paste viscosity and water and solubility indexes. TP was reduced in sorghum depending on the genotype (10 and 40%) after extrusion whereas in mixtures with CP, TP increased. The extrusion promoted a decrease of AC, but mixtures with CP still had higher AC than those with only sorghum. The present study indicates that it is possible to produce sorghum extrudates and CP with good antioxidant properties and phenolic compounds.

Nanubala et al., (2013) developed sorghum-based extruded snacks. Results from preliminary lab-scale extrusion experiments were used to design a 2×5 factorial pilot-scale study. Two blends of sorghum flour and corn flour were prepared (6:1 and 5:2 w/w ratios) as the controls. Three different sources of protein—whey protein isolate, defatted soy flour, and mixed legume flour—were added to the sorghum/corn flour blends at 30%. A 50:50 blend of defatted soy flour and whey protein isolate was also added at 30% to the sorghum/corn flour blends. The resultant ten formulations were extruded on a pilot-scale twin-screw extruder to investigate the effects of sorghum/corn flour ratio and protein addition on product expansion, microstructure, mechanical properties, and sensory attributes. Expansion ratio of extruded product increased at the higher level of corn flour, and decreased with the incorporation of protein sources. Extrudates with defatted soy flour had a lower expansion ratio (5.3–5.4) than those with whey protein isolate (7.7–7.9), legume flour (7.1–9.9), or whey protein isolate defatted soy flour (6.1–6.9). Extrudate microstructure, obtained by X-ray microtomography, corresponded well with expansion characteristics. Extrudates with defatted soy flour had the lowest cell diameter. Average crushing force (ranging from 40.9 to 154.87 N) was lower for extrudates with a higher level of corn flour. However, contrary to expectations, crushing force and crispness work both decreased with incorporation of protein sources. Consumer acceptability results showed that the addition of protein sources enhanced taste and overall acceptability of the extruded snacks, with the treatment sorghum/corn flour 5:2 and whey protein isolate-defatted soy flour as the protein source having significantly higher ratings than the other treatments.

Jose et al., (2015) were examined the impact of these Andean grains on the sensory and physical properties of corn-based extruded snacks. Extrudates containing increasing contents of amaranth, quinoa or kaniwa (20, 35 and 50% of solids) were prepared under the same extrusion conditions. Extrudates with higher contents of amaranth, quinoa and kaniwa were rated less crispy, less crunchy and less adhesive with less hard particles. Temporal analysis showed that with increasing contents of amaranth, quinoa and kaniwa, crispiness and crunchiness were the most dominant attributes during mastication while the dominance of roughness reduced considerably. Porosity and wall thickness, measured by X-ray microtomography, were linked to the perception of crispiness and crunchiness, respectively. Despite the observable changes in the physical and sensory characteristics of extruded corn-based snacks, the incorporation of amaranth, quinoa and, particularly, ka~niwa (the least studied Andean grain) showed promising results for the development of novel gluten-free products.

SooriyaArachchige et al., (2019) were evaluated Soluble, insoluble and total dietary fiber contents, rapidly and slowly digestible starch contents, arabinoxylans, β-glucans, fructans, resistant starch, amylose and total sugar contents, minerals and trace elements compositions and proximate compositions of three finger millet varieties, namely Ravi, Rawana and Oshadha using standard protocols. There were no significant differences ($P \geq 0.05$) among the rapidly digestible starch, arabinoxylans, β-glucans, fructans, amylose, total sugar, protein, crude fat and crude fiber contents of Ravi, Rawana and Oshadha varieties. Total dietary fiber contents varied between 13.01% (Ravi) and 13.79% (Oshadha). Slowly digestible starch contents ranged from 43.38% (Ravi) to 49.15% (Oshadha) and resistant starch contents ranged from 3.75% (Ravi) to 4.58% (Oshadha). Ash content of Ravi (3.22%) was significantly higher ($P < 0.05$) than ash contents of other two varieties. Average sodium, magnesium, potassium, calcium, iron, zinc and phosphorous contents of three finger millet varieties were 12.04, 141.78, 407.15, 345.62, 3.49, 1.89 and 331.07 mg/100 g, respectively. Findings of the present study indicated that studied finger millet varieties were good sources of dietary fibers (including resistant starch) as well as minerals and trace elements (especially potassium, calcium, phosphorous and iron) when compared to commonly consumed cereals such as rice and wheat.

JinleXianga et al., (2018) were investigated the profiles of phenolic compounds and antioxidant capacities of four finger millet varieties harvested in northern Malawi. The total phenolics, flavonoids and condensed tannins in the free fractions ranged from 114.43 to 179.19 mg ferulic acid equivalent (FAE)/100g, 90.24 to 202.94 mg catechin equivalent (CE)/100g and 31.76 to 83.59 mg CE/100g, respectively. Total phenolic contents of the bound fractions ranged from 58.27 to 123.23 mg FAE/100g. Twenty phenolic compounds were identified in the free fractions including eighteen flavonoids, with catechin and epicatechin being the predominant flavonoids. Seventeen phenolic compounds were identified in the bound fractions, with ferulic acid being the predominant one. Ten of the identified polyphenols were firstly reported in finger millet. Darker colored finger millet varieties had higher phenolic contents and antioxidant properties than the lighter colored ones. Finger millet can be used as healthy food material and natural antioxidant resource.

Sharmila.B and Athmaselvi.K.A (2017). Developed the snacks with under-utilized millets like Kodo millet and legumes like horse gram and Chick pea. Horse gram (36%) was subjected to seven different treatments like (soaking, sprouting, preconditioning) before blending into the mix containing Kodo millet (52%) and chick pea(12%). The process parameters were optimized at constant barrel temperature of 150$^0$C and constant screw speed of 275 rpm. The results were compared to the control containing no horse gram. The physio-chemical properties, nutritional composition and organoleptic properties of extrudates were analyzed. The results indicated that sprouted horse gram blended into composite flour produced extruded snacks which had more preference according to taste, expansion, sensory, color.

## III-MATERIALS AND METHODS

The present investigation entitled "A Study on Development of Extruded Products incorporated with Millets" was conducted at Rajclassic Foods Pvt Ltd, Located at Hyderabad,Telangana State, India.

**3.1 Materials**

**3.1.1 Sorghum(Sorghum bicolor (L.) Moench)**

Whole Sorghum grains were procured from local market and further dehulled and grounded into flour

**3.1.2 Finger Millet (Eleusine coracana (L.) Gaertn.)**

Whole Finger millet (Ragi) procured from local super market

**3.1.3 Barnyard millet (Echinochloa frumentacea)**

Whole barnyard millet (Samalu) used was procured from DDS, Krishi Vigyan Kendra, Zahirabad, Sangareddy District of Telangana state.

**3.1.4 Chick pea (Besan) flour** (Cicer arietinum)

Chick pea was procured from the local market.

**3.1.5 Salt**

Iodized branded salt was procured from local market.

**3.1.6 Spice Mix**

All the spices required for preparation of spice mix were obtained from local market of Hyderabad. The spice mix was prepared from the following spices

1. Dry mango (mangifera indica) powder
2. Black pepper (piper nigrum) powder
3. Cumin (cuminum cyminum) powder
4. Chillies (capsicum annum) powder
5. Black salt
6.Citric acid

The spices were blended in different proportion in order to have an acceptable taste

**3.1.7 Refined Rice bran Oil**

Edible refined Rice bran oil was procured from local market of Hyderabad, for spraying the spice powder on Extrudates.3.1.8 Chemicals:The chemicals used in the investigation are of analytical grade. Sodium Hydroxide, Hydrochloric acid, Sulphuric acid,2,2′-diphenyl-1-picrylhydrazyl(DPPH), Sodium sulphate.Sodium carbonate, Copper sulphate , ethyl acetate,Ferulic acid, methanol and Petroleum ether were obtained from Molychem, India. Bromocresol green, Phenolphthalein, Boric acid, methyl orange and methyl red indicator were obtained from Qualigens, India

**3.2 Equipments**

**3.2.1. Laboratory equipments**

Hot-air oven (VT 43810, Mack Equipments, India), Muffle Furnace, Kjeldhal Apparatus (Kelplus-Distyl EM), Soxhlet Apparatus SCS 6, Pelican Equipments, India), Fiberanalyzer (Fibra Plus FES6, Pelican Equipments, India), Spectrophotomet (Elico India),Weighing balances (Mettler AE 163) and (Sartorius CP225D) were used during the project.

3.2.2 Dehuller

The dehuller consists of a two or more emery rollers, fixed to shaft which is rotating inside a barrel. When the grains fed to the dehuller the outer layers of grains were removed by rubbing action between the grains and rollers covered with

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 2 Feb 2021, pp: 01-15 www.ijaem.net ISSN: 2395-5252

emery coating which helps in preventing damage to the grain by providing resilience, mounted on a shaft driven by a motor. It also has an aspirator for blowing off the husk from the dehulled grains. The dehuller works on the principle of compression and shear force. In the emery type of dehuller used in this experiment (Figure. 1), the abrasive forces and the compression forces are generated by the roller and the grains present in the chamber as shown in Plate 2. Plate. 1 Emery Roller type dehuller

The husk or chaff was collected from a separate outlet with the help of an aspirator. The husk and the other foreign matter were separated using a cyclone separator. The whole grain sorghum and barnyard millets were dehulled separately in the dehuller and removed outer layer. Dehulling of whole sorghum and Barnyard millet grains was carried an emery roller type dehuller. The maximum capacity of the dehuller was 25 kg in one time for grains like sorghum and pearl millet. Since the grains of Barnyard millet a little smaller in size as compared to pearl millet, the maximum capacity was taken as 23 kg. The amount of feed was 22 kg. The dehulling was carried out for 30 minutes. The dehulled grains were grounded in mill into flour for composite flour preparation before extrusion cooking.

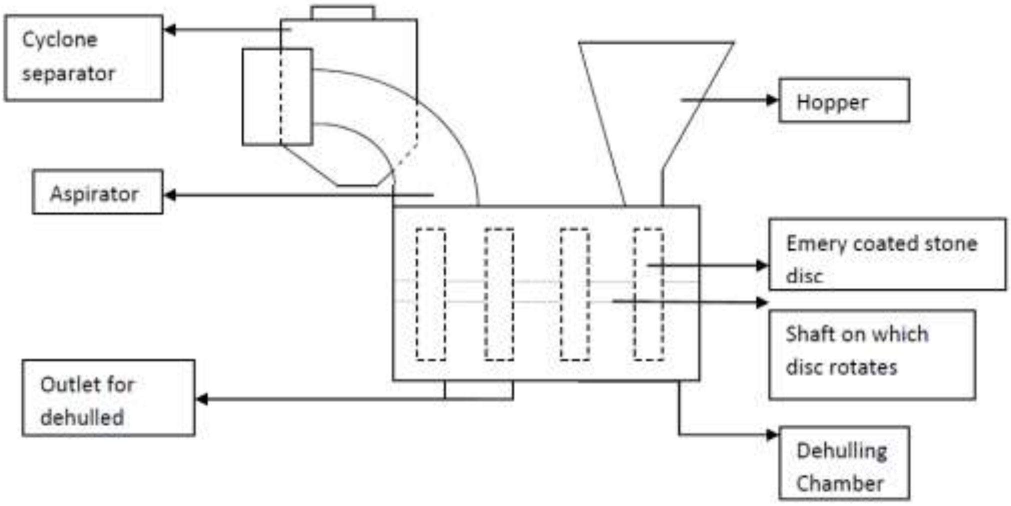



**Fig. 1**. Schematic Diagram of an Emery Roller type dehuller

a) Coefficient of Dehulling: It is obtained by dividing the weight of decorticated grains by the initial weight taken.

$$\text{Coefficient of Dehulling} = \frac{\text{weight of decorticated grains}}{\text{initial weight of grains taken}}$$

b) Coefficients of Wholeness: It is obtained by dividing the weight of undamaged grains by the total weight of 100 grains taken in the sample.

$$\text{Coefficient of Wholeness} = \frac{\text{weight of undamaged grains in the sample of 100 grains}}{\text{total weight of the 100 grains taken}}$$

### 3.2.3 Flour mill

In the experiment conducted, the milled flour is required for extrusion cooking. Milling of sorghum, finger millet and barnyard millets were carried out in an emery domestic flour mill at B. Yellaiah Stores in Kukatpally, Hyderabad. The milling machine called as Atta chakki (Flour mill, Bimco, India) and had the specifications mentioned in Table 1. Grain is poured from hopper and there is a slot provided just under the opening of hopper so as to control flow of grains manually. Particle size of flour maybe controlled using a control given on side of main grinding chamber. Using this control spacing between the two rolls maybe adjusted, resulting in variation of particle size. After grinding flour is collected from a outlet given at the right side of grinding chamber. Flour flows continuously from outlet, which shows that grinding is of continuous type and particle size is reduced to 100 % pass through mesh no. of 18 (853µ size).

**Table 1 :** Specifications of the Atta Chakki Machine

| **Specifications of Machine** | **Parameters** |
|---|---|
| Stone Size | 16 inches |
| Capacity | 50 kg |
| Belt Width | 4 inches |
| Belt Material | Rubber |
| Belt Length | Variable |
| Belt Company | Good Year |
| Manufacturer | Bimco |
| Speed | 720 rpm |
| Power | 10 HP |
| Phase | 3 Phase |

**3.2.4 Extruder**

Jinan Delon(DL SERIES DL70 china made) twin screw co-rotating, self wiping extruder with length/ diameter ratio of 25, screw speed up to 600 rpm and outer screw diameter of 25 mm and capacity of 100kg/hr was used. The screw configuration (from feed section to die) used to process the extrudates consisted of three sections with forward elements. First section had fourelementseach 50 mm length having three screw flights and13 mm pitch. The second zone consisted of fiveelements each 50 mm in length having four screwflights and 10 mm pitch. Third zone again consistedof five elements each 50 mm in length having sixscrew flights with 7 mm pitch. The total length ofthe screw was 700 mm with 14 elements in threezones. The extruder was equipped with a bulk solidsmetering feeder (KTRON T20, Switzerland). A diewith a single circular opening (2.5 mm diameter),equipped with a rotary die face cutter (speed of 130rpm) was used.

**3.3 Methods**

**3.3.1 Composite flour preparation**

Flours were blended for obtaining different flour compositions of Sorghum, Finger Millet, Barnyard millet with Chick Pea flour, using 100 kg ribbon blender. 100 kg of final composite flour blends were prepared according to compositions shown in Table 8.These blends were chosen according to preliminary tests without jamming of extruder and for acceptable product's physical characteristics as well as better nutritive value in the final product.

**Table 2:** Different flour compositions for extrusion cooking

| **Ingredients** | **Control (%)** | **Sample T1 (%)** | **Sample T2 (%)** | **Sample T3 (%)** |
|---|---|---|---|---|
| Dehulled Sorghum Flour | 100 | 50 | 40 | 30 |
| Finger Millet flour | - | 10 | 15 | 20 |
| Dehulled Barnyard millet flour | - | 10 | 15 | 20 |
| Chick Pea flour | - | 30 | 30 | 30 |

**3.3.2 Flour Conditioning**

The blended samples were conditioned up to to 21–22% (w.b) moisture by spraying with a calculated amount of water and mixing continuously at medium speed in a blender. The samples were put in buckets and stored at 4°C overnight. The feed material was then allowed 3hr to equilibrate at room temperature prior to extrusion. This preconditioning procedure was employed to ensure uniform mixing and hydration and to minimize variability in the state of the feed material.

### 3.3.3 Extrusion Cooking

Feeding of the pre conditioned composite flour to a twin extruder was accomplished by using a twin screw volumetric gravity feeder. Based on the most stable product expansion and stability of the extruder conditions the extrusion conditions were used (Figure 2). The temperature of the two barrel zones of extruder from feeder end were set at 115°C and 90°C respectively. Samples were collected at the most stable die temperature which was around 80°C. Screw speed was set up at 400 rpm and equipped with 3-mm restriction die or nozzle to extruder. Constant feeding rate was kept throughout the experiments. Three replicate samples were extruded.

### 3.3.4 Post - extrusion treatment

The samples were dried at 120°C in 5 layer belt dryer with the capacity of 50kg. The final dried samples contained a maximum of 5.0% (db) moisture.

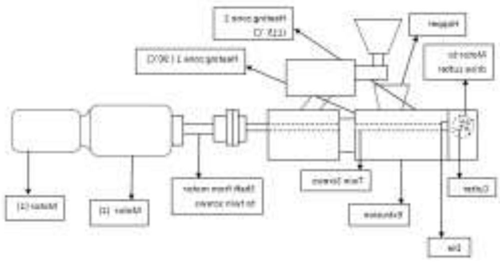


**Figure 2.**Schematic diagram of the lab model twin screw extruder

### 3.4. Physical properties

Physical properties such as piece density, bulk density, moisture retention, expansion ratio and mass balance are to be calculated so as to compare different extrudates from different blends with 100% whole barnyard millet.

### 3.4.1 Piece density

Piece density was calculated using a vernier caliper. 15 similar test samples were taken and using vernier caliper, length and diameter of each of 15 pieces was measured. Mass of 15 pieces was taken and average length (h), radius(r) and mass were calculated.

$$\text{Piece density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Volume} = \pi x r^2 \times h$$

### 3.4.2 Bulk density

Bulk density is calculated using a measuring cylinder. The extruded samples are filled up to 100 ml of volume and then the weight of the sample is taken. Hence the weight of 100 ml in grams is divided by 100 to obtain bulk density in g/cc.

### 3.4.3 Expansion Ratio

Expansion ratio is calculated using a vernier caliper. 15 samples were taken and diameter of each sample was measured using a vernier caliper and expansion ratio was calculated using given formula;

$$\text{Expansion ratio} = \frac{\text{Diameter}}{\text{Die diameter}}$$

### 3.4.4 Moisture retention

Moisture retention was measured using the method given in heading 2.2.6.1 using hot air oven method. Moisture content is measured for extruded product before drying and after drying as well and accordingly moisture lost during extrusion cooking and during drying can be calculated.

### Sensory Properties

The sensory assessments were conducted in Quality Control Lab Rajclassic Foods Pvt Ltd., Hyderabad. The panel of 25members consisted of staff and trained panel members of the factory workers. The panelists were naive to project objectives. The samples (Control, samples (T1, T2, T3 and T4)) were coded with three digit-numbers and served with the order of presentation counter-balanced. Panelists were provided with a glass of water and, instructed to rinse and swallow water between samples. They were given written instructions and asked to evaluate the products for acceptability based on its appearance, flavour, texture, taste, color and overall acceptability using nine-point hedonic scale (1 = dislike extremely to 9 = like extremely; Meilgaard et al., 1999 ).

### 9-point hedonic scale

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 2 Feb 2021, pp: 01-15 www.ijaem.net ISSN: 2395-5252

As given in Table 7, on basis of hedonic rating scale 1 is for liked extremely and as the number increases likeness decreases with 9 being worst.

| | |
|---|---|
| 9 | Like extremely |
| 8 | Like very much |
| 7 | Like moderately |
| 6 | Like slightly |
| 5 | Neither like or dislike |
| 4 | Dislike slightly |
| 3 | Dislike moderately |
| 2 | Dislike very much |
| 1 | Dislike extremely |

**Statistical analysis**

The analysis of variance of the data obtained was done by using Completely Randomized Design (CRD) for different treatments as per the methods given by Panse and Sukhatme (1967). The analysis of variance revealed at significance of $P < 0.05$ level, S.E. and C.D. at 5 % level is mentioned wherever required

## IV-RESULTS AND DISCUSSION

Sincere efforts were made to standardize the composite flours by blending different proportions of cereals (sorghum, ragi and barnyard millet grains) and chickpea flour. The prepared composite flours were utilized for production of extruded foods. The extrudates qualities were determined by physical properties, nutritional composition, functional Properties and Sensory acceptability. The techno-economic feasibility of accepted functional extruded snack food was assessed. The results are discussed as below under following suitable heads and subheads

### 4.1 Dehulling

The emery roller type dehuller gave coefficient of hulling as 86.57 % and 74.31% for Sorghum and barnyard millet respectively as given in Table 3 which is an indicator of excellent performance. Hence choosing emery roller type dehuller for decortications of grains is a good option. The coefficient of wholeness is obtained as 100 % which represents no breakage of grains during hulling. This is a reflection of highly friable nature of barnyard pericarp which is probably related to the fact that it, almost uniquely among cereals, contains starch granules (Taylor, 2003).

**Table 3: Results and parameters of dehulling process**

| Sample | Capacity of Dehuller (kg) | Time of dehulling (min) | Coefficient of wholeness (%) | Coefficient of hulling (%) |
|---|---|---|---|---|
| Sorghum | 15 | 30 | 100 | 86.57 |
| Barnyard millet | 15 | 30 | 100 | 74.31 |

### 4.2 Composite Flours

Cereals and pulses are used as blend to produce nutritionally balanced snack foods. The protein quality of millets and pulse combination better than that of millet alone (Harper, 1981). A preliminary extrusion trial was conducted with different proportions of composite flour blends of Sorghum, Finger millet, Barnyard millet: Bengal gram at constant moisture in composite flours. The blending ratios of composite flours were finalized based on the most stable product expansion. The blended ratios of flours to prepare composite flours are presented in Table 2. These composite flours were used to produce the better quality of extrudates with maximum retention of nutrients in the final products.

### 4.2 Extrusion Cooking

Jinan delon DL 70 (china made) twin screw co-rotating, self wiping extruder had manual and automatic flour feeding feature and hence the slight variations were incurred in feed rate and mass flow rate as shown in Table 4 below.

Two different temperature zones were present in the extruder. Zone 1 with 90°C temperature led to cooking of the flour. Zone 2 with 115°C was required to make the water super heated. High pressure was present in this zone to prevent water from vaporizing. As the cooked flour with super heated flour comes out of die, due to pressure drop, the water evaporates and it leads to puffing of the cooked product.

**Mass balance during extrusion cooking**

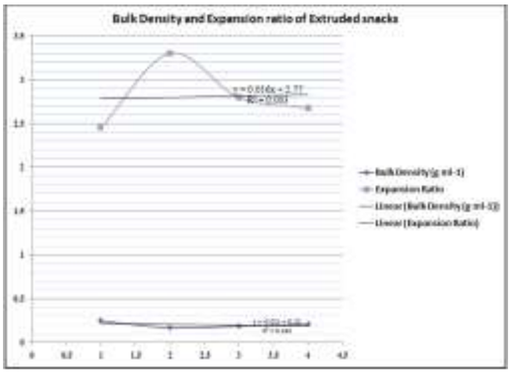
| Sample | Initial weight (kg) | Final Weight (kg) | Yield (%) | Loss (%) |
|---|---|---|---|---|
| Control | 105.6 | 84.82 | 80.33 | 19.67 |
| T1 | 98.46 | 86.66 | 88.02 | 11.98 |
| T2 | 96.35 | 83.82 | 87.0 | 13.0 |
| T3 | 102.6 | 88.28 | 86.05 | 11.72 |

4.3 Physical properties of extrudates:The physical properties of the extrudates reflect the effectiveness of the process and suitability of selected ingredients. Even after 50 years of food extrusion research, one finds a lot of variation in the sample size as well as in the methods of evaluation of properties of extrudates. Since methods of characterizing raw materials and evaluating extrudates are not standardized. Further the research results are also not interpreted uniformly more over repeatability of the results for scaling up becomes more difficult in the extrusion cooking process.The flour particle size, moisture adjusted to 21-22% (w.b), feed rate, temperature, screw speed and die speed were kept constant throughout the experiments. Bulk density :Bulk density play vital role in handling, packaging, and transportation of extruded snack foods. The bulk density was measured in g/cc and the results are displayed in Table 6. It ranged from 0.17 to 0.25 g $ml^{-1}$. Bulk density did not follow any particular trend and was minimum for extruded Sample–T1 (0.17 ± 0.02 g $ml^{-1}$) followed by Sample–T2 (0.19 ± 0.03 g $ml^{-1}$) while it was maximum for control sample (0.25 ± 0.03 g $ml^{-1}$).

Bulk density of extruded products

| Sample | Bulk Density (g $ml^{-1}$) |
|---|---|
| Control | 0.25 ± 0.03 |
| (T1) | 0.17 ± 0.02 |
| (T2) | 0.19 ± 0.03 |
| (T3) | 0.21 ± 0.01 |

Lower bulk density represents higher expansion ratio which is a desirable characteristic in snack food. An extrudate with high bulk density is characterized by a more uniform and continuous protein matrix, with no air pockets and poor hydration properties (Filli and others 2012). High BD is usually accompanied by poor perception by the consumer. It can be seen from the Table 6 that the bulk density of extrudates decreases tremendously due to high protein content in the final product. Similar types of results were observed by Singh et al., (2006) in scientific literature.




**Bulk density and Expansion ratio of Extruded snacks**

4.3.3 Moisture Retention

Moisture lost during the extrusion process is approximately 14% - 15% for extruded products prepared from the blends of dehulled Sorghum, barnyard millet, finger millet + chick pea flours.


Control sample


T1 sample

**Table 8:** Moisture retentionof extrudates samples

| Sample | Moisture before extrusion (%) | Moisture after extrusion before drying (%) | Moisture after extrusion after drying (%) | % of Moisture loss |
|---|---|---|---|---|
| Control | 21.05 ± 0.13 | 10.96 ± 0.00 | 5.75 ± 0.22 | 27.31 |
| (T1) | 21.41 ± 0.42 | 10.82 ± 0.22 | 4.29 ± 0.28 | 20.03 |
| (T2) | 21.67 ± 0.14 | 11.36 ± 0.19 | 4.87 ± 0.15 | 22.47 |
| (T3) | 21.63 ± 0.10 | 11.53 ± 0.14 | 4.94 ± 0.31 | 22.81 |


T2 sample


T3 sample

**4.4 Proximate Analysis**

Proximate analysis was carried out for extruded snacks for finding out the nutritional property of the product. On comparison of proximate analysis of control and samples as shown in Table 9 and Figure 5, it can be seen that there is major reduction in fat content on dehulling. This is due to removal of germ present in grain during dehulling which is rich in fat.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 2 Feb 2021, pp: 01-15 www.ijaem.net ISSN: 2395-5252

**Table 9. Chemical composition of Extruded snacks (per 100 gm of sample)**

| Nutrients | Control | T1 | T2 | T3 |
|---|---|---|---|---|
| **Moisture** | **5.75 ± 0.22** | **4.29 ± 0.28** | **4.87 ± 0.15** | **4.94 ± 0.31** |
| **Calories (kcal)** | **321.5** | **350.4** | **316.7** | **315.2** |
| **Protein(g)** | **10.1** | **14.4** | **13.2** | **13.1** |
| **Fat(g)** | **2.9** | **3.9** | **3.6** | **3.6** |
| **Carbohydrates (g)** | **63.7** | **64.4** | **57.8** | **57.5** |
| **Dietary Fiber (g)** | **7.2** | **10.2** | **8.4** | **8.6** |
| **Total Minerals (g)** | **1.3** | **1.8** | **1.8** | **1.9** |
| **Total Phenolic Content (mg AG/g)** | **3.1** | **3.2** | **2.9** | **2.9** |
| **Antioxidant Activity DPPH DPPH+(IC50) (mg/ml)** | **6.3** | **5.5** | **4.7** | **4.4** |

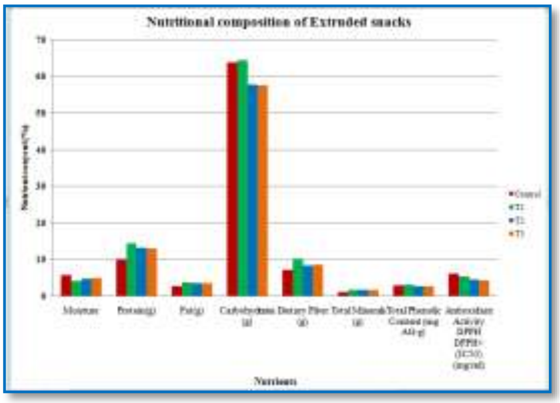



**Figure 5: Nutritional Composition of Millets based extruded snacks**

**Table: 10 Mean sensory score values for the Extruded snack food**

| **Extruded samples** | **Sensory attributes** | | | | | |
|---|---|---|---|---|---|---|
| | **Appearance** | **Colour** | **Flavour** | **Texture** | **Taste** | **Overall acceptability** |
| **Control** | 7.8 | 7.0 | 7.0 | 7.9 | 7.0 | 7.7 |
| **T1** | 8.3 | 8.6 | 8.4 | 8.8 | 8.6 | 8.9 |
| **T2** | 7.5 | 7.9 | 7.8 | 8.9 | 8.2 | 8.5 |
| **T3** | 7.2 | 7.4 | 7.2 | 8.0 | 8.0 | 7.7 |
| **Mean** | 7.7 | 7.7 | 7.6 | 8.4 | 8.3 | 8.2 |
| **C.D at 5% level** | 0.47 | 0.7 | 0.63 | 0.53 | 0.67 | 0.6 |
| **S.E±** | 0.2353 | 0.3516 | 0.3142 | 0.2664 | 0.2976 | 0.2985 |

**4.6 The Techno-Economic Feasibility of Nutri-Cereal based Extruded Snack Food**

The techno-economic feasibility of extruded snack was determined by calculating the total cost of production for 1 kg of product.

The estimation of cost of production was done by using standard calculation method. By considering the raw material cost, processing cost (@ of 10% of raw material cost) and miscellaneous cost (@ of 2% of raw material cost), the unit cost of production and the net cost were assessed. The price for 1kg of raw materials and production cost for 1kg of extruded product from composite flour sample-B is presented in Table 11.

The material balance of extruded product prepared using composite flour sample was found to be an around 880 gm of extruded product from 1 kg of composite flour.

The total cost for production of 880 gm of extruded snack food was around 99:47 rupees. For

20 g snack priced @ Rs. 5, the number packets from 880g is 44. The projected gross income from 1kg of processing of raw materials is Rs.220. By comparing the costs techno- economic feasibility of prepared therapeutic extruded snack food was good.

**Table: 11 Cost of production (for 1 kg of accepted extruded snack food)**

| Sl. no | Details / Raw materials | Cost (Rs /kg) | Cost for production of 1kg product |
|---|---|---|---|
| 1. | Sorghum (500g) | 18:00 | 9.0 |
| 2. | Finger millet (100g) | 35.00 | 3.5 |
| 3. | Barnyard millet (100g) | 80:00 | 8.0 |
| 4. | Bengal gram (300g) | 70:00 | 33.0 |
| 6. | Edible oil | 70:00 | 3.0 |
| 7. | Salt | 5:00 | 0.50 |
| 8. | Dry green mango powder (10 g) | 300:00 | 3.0 |
| 9. | Black pepper powder (10 g) | 900:00 | 9.0 |
| 10. | Cumin powder (10 g) | 180:00 | 1.80 |
| 11. | Black salt (10 g) | 30:00 | 0.50 |
| 12. | Chilli powder (15 g) | 150:00 | 1.50 |
| 13. | Citric acid (0.2 g) | 80:00 | 0.5 |
| **A) Total Cost of raw materials** | | | 73.3 |
| **B).Processing cost (@ 0f 10% 0f raw material cost)** | | | 7.5 |
| **C) Packaging cost** (@ of 20% of raw material cost) | | | 15.0 |
| **D) Other charges @ 5%** | | | 3.67 |
| Total cost (A+B+C+D) in Rs. | | | 99.47 |
| Total Net Product weight after processing 1kg | | | 880 g |
| Packaging @20g, number packets are 44 @ Rs 5.0 | | | 220 |

## V-SUMMARY AND CONCLUSION

The results obtained during present investigation on "A Study on Development of Extruded Products incorporated with Millets" are enough to draw summary and conclusion as follows.

SUMMARY

The resilient millets are smart nutritious foods and they can be explored to develop ready to eat healthy Ready to Eat (RTE) items like extruded snacks with composite mixture of nutri-cereals (sorghum, Finger Millet, Barnyard Millet) and Chickpea flour.

Further, the attempts have been made to optimize extrusion cooking parameters with composite millet flours (Sorghum, Finger Millet, Barnyard Millet) at different levels. 100 % dehulled sorghum based extruded snacks were kept as control sample and in all the composite flour samples chick pea flour kept as constant at 30%. The innovative composite flour blends were made to maximize expansion ratio of extrudates and also enrich nutrients like protein, fiber, functional compounds like to total phenolic compounds and antioxidants in the RTE snacks.

Bulk density did not follow any particular trend and was minimum for extruded Sample–T1 (0.17 ± 0.02 g ml-1) followed by Sample–T2 (0.19 ± 0.03 g ml-1) while it was maximum for control sample (0.25 ± 0.03 g ml-1). Expansion ratio is a critical factor for puffed cereal and snack products, as it is significantly related to the eating characteristics. The extruded sample –T1 has more expansion ratio than extruded sample –T2 and extruded sample-T1. 100 % dehulled sorghum has less expansion then other samples.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 2 Feb 2021, pp: 01-15 www.ijaem.net ISSN: 2395-5252

Maximum content of protein was found in sample T1 (14.4g) than the sample-T2(13.2 g) and sample-T1 (13.1g). This may be due to major proportion of composite flour in sample-T1 (Sorghum: Finger Millet: Barnyard Millet : Chick pea flou; 50:10:10:30). The pulse contains more proteins than millets.

The result from the nutritional analysis (Table 9) shows That carbohydrates content was maximum in case of Sample T1 (64.4g) followed by controlled sample, T2 and T3. The difference in carbohydrates content in the sample may be attributed the presence of major proportion of sorghum and finger millet in the extruded snacks. The Crude fiber content was maximum in case of sample T1 (10.2g) followed by sample- T2, T3 and 100% dehulled sorghum. The difference in fiber content in the sample may be attributed the presence of major proportion of finger millet and barnyard millet in the extruded snacks.

The Total Phenolic content of extrudates indicated in the table 9. There is no significant difference among the samples. Reduction in sorghum flour in the subsequent samples reported decreased trend of total phenolic content. The highest total Phenolic content was found in the sample-T1 (3.2). This pattern is due to the higher levels of sorghum flour, which has higher content of phenolic compounds when compared to other millets.

The antioxidant activity of extruded snacks decreased with added composite millet (Finger millet and Barnyard millet) flour from 10 to 20%. The highest antioxidant activity was noted in the control sample (6.3mg/ml). This pattern is due to the 100 % sorghum flour, which has higher content of antioxidant compounds when compared to other millets.

The mean sensory values of overall acceptability for control, T1, T2 and T3 were found as 7.7 8.9, 8.5 and 7.7 respectively on the Hedonic scale. All the combinations of flours in composite extruded snacks valued in between like moderately to like very much. Highest score was observed in extruded sample T1, which was made from the blend of Sorghum: Finger Millet: Barnyad Millet: Chickpea (50:10:10:30). It was interesting to note that the both sample T2 and T3 were rated as liked very much. The overall acceptability of extruded snack food could be attributed to the different characters of appearance, colour, taste, flavour and texture of the final product. It is revealed from the scores of the overall acceptability that the nutri cereals grains (Sorghum: Finger Millet: Barnyad Millet) and Chickpea can be successfully mixed to the level of (50:10:10:30) respectively to produce a better acceptable product.

After organoleptic assessment of extruded snack foods, the extruded food prepared from flours of Sorghum: Finger Millet: Barnyad Millet: Chickpea in the ratios 50;10;10:30 respectively have a best sensory acceptability than remaining other two samples and control.

## CONCLUSION

The physical, nutritional and sensory properties of millet based Ready to Eat (RTE) extruded snacks prepared from composite flours of Millets and chick pea were evaluated. It could be concluded that, millets and pulses composite flour can be partially or fully replace commercial snacks made from rice, corn etc., with the nutri-cereals called sorgum and millets to develop functional ready to eat healthy extruded snacks without compromising the sensory attributes. In terms of physical properties extruded sample T1 (Sorghum: Finger Millet: Barnyad Millet: Chickpea in the ratios 50;10;10:30) has maximum expansion ratio (3.30) and lower bulk density (0.17g/ml) than other samples. The nutritional analysis showed higher nutrients content in sample T1 when compared to the control and other samples. The mean sensory values of overall acceptability for control, T1, T2 and T3 were found as 7.7 8.9, 8.5 and 7.7 respectively on the Hedonic scale. All the combinations of flours in composite extruded snacks valued in between like moderately to like very much. Highest score was observed in extruded sample T1, which was made from the blend of Sorghum: Finger Millet: Barnyad Millet: Chickpea (50:10:10:30).

## REFERENCES

[1]. Amadou, I., Mahamadou, E. G., & Le, G-W. (2013). Millets, Nutritional composition, some health benefits and processing- A Review. Food Science and Technology, 25(7), 501- 508.

[2]. Anitha S, Kane-Potaka J, Tsusaka TW, Tripathi D, Upadhyay S, Kavishwar A (2019).Acceptance and impact of millet-based mid-day meal on the nutritional status of adolescent school going children in a Peri urban region of Karnataka state in India. Nutrients 11: 1–16.

[3]. Anju T and Sarita S (2010). Suitability of Foxtail Millet (Setaria italica) and Barnyard Millet (Echinochloa frumentacea) for Development of Low Glycemic Index Biscuits. Malasian Journal of Nutrition. 16 (3), 361-368.

[4]. Apea-Bah, F. B., Minnaar, A., Bester, M. J., &Duodu, K. G. (2016). Sorghum-cowpea

[5]. composite porridge as a functional food, Part II: Antioxidant properties as affected by simulated in vitro gastrointestinal digestion. Food Chemistry, 197(Pt A), 307-315.

[6]. Arhaliass, A., Bouvier, J. M., & Legrand, J. (2003). Melt growth and shrinkage at the exit of the die in the extrusion-cooking process. Journal of Food Engineering, 60(2), 185–192.

[7]. Betab (2018). Profile of phenolic compounds and antioxidant activity of finger millet varieties. Food Chemistry (2018), doi: https://doi.org/10.1016/ journal food chemistry.2018.09.120

[8]. Bidyut P. Mishra, Geeta Chauhan, S. K. Mendiratta, P. K. Rath and B. A. Desai (2014). Effect of Barnyard Millet Flour on the Quality Characteristics of Dehydrated Chicken Meat Rings. Indian Veterinary Journal. 91 (08): 45 – 49.

[9]. Bouzaza, D., Arhaliass, A., & Bouvier, J. M. (1996). Die design and dough expansion in low moisture extrusion-cooking process. Journal of Food Engineering,

International Journal of Advances in Engineering and Management
ISSN: 2395-5252


# IJAEM

Volume: 03 Issue: 02 DOI: 10.35629/5252

www.ijaem.net
Email id: ijaem.paper@gmail.com