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# Development and physico-functional evaluation of protein rich hot extruded snack with jowar millet

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**Abstract**

The market segment is experiencing the rise in demand for the snack foods, with the extruded products. Extrusion is a HTST process used to develop innovative value-added products from cereals pulses and millets. Protein rich jowar based extruded snack was developed with composition ratio of flours jowar flour: corn flour: soy flour: roasted Bengal gram flour (50:30:15:5) respectively. Extruded snack with 100% corn flour was taken as control. The extrusion conditions followed for extrusion were barrel temperature (120 ºC; 140 ºC), feed moisture (14%, 16%), screw speed (1320 rpm), feeder speed (900 rpm), cutter speed (1140 rpm) and exit diameter of the die (4 mm). The developed extrudates were subjected to physico-functional and sensory analysis. When compared to the control sample, decrease in length (9.91%), diameter (31.49%), expansion ratio (25%), bulk density (68.09%), sectional expansion index (52.64%) and tap density (41.66%) and increase in specific length (21.42%) was observed. There was 28.83% decrease in water absorption index (WAI) in JCSR when compared with CMAK. There was 26.32% decrease in water solubility index (WSI) in JCSR when compared with CMAK. The acceptability index (AI%) of JCSR was 86.9% and CMAK was 76.2 which show the jowar extruded snacks were more acceptable than control sample.

**Keywords:** Jowar, corn, hot extrusion, physical parameters, functional parameters

## Introduction

Ready-to-eat (RTE) snack foods are gaining popularity among consumers due to their taste, texture, convenience, affordability, and appealing look. The demand for snack foods is due to per capita income, changing lifestyles, and shifting food purchasing and consumption patterns (Patel and Rathod, 2017) [19]. Various convenience foods made from cereals, pulses, millets, pasta, noodles, baked products, extruded products, weaning food, and fermented food serve as RTE snacks (Temgire *et al*., 2021) [31].

Extrusion cooking is a versatile processing technique that modifies raw materials, potentially values agri-food by-products, and contributes to sustainable food processing. It involves forcing a blend of composite ingredients through a die at certain temperature by minimizing the energy and usage of water (Soja *et al*., 2024) [28]. Extrusion cooking is under the HTST (High temperature short-time) method, established to develop innovative value added RTE (ready-to-eat) snack foods. The technology significantly changes proteins, starch, vitamins, fibre and lipids. It also enhances nutritional aspects and new advanced developments in extrusion technology and their applications in food technology (Chandresh and Priya, 2020) [5].

Among the millets, jowar (*Sorghum bicolor*) is the fifth most important cereal crop grown in the world. It is an important staple crop in semi-arid regions of Africa and India because it has drought tolerance. Traditionally, jowar was used to make flatbread, thick and thin porridges, snacks and other products. Jowar is low in protein content but contains more cross-like prolamins than other cereals. Therefore, there is a need to develop sorghum-based extrudates combined with high protein sources (Devi *et al*., 2013) [8]. Starch is the crucial component for sorghum grain, followed by proteins, and fat (Tadesse *et al*., 2019) [32].

Soybean is a rich protein source; it requires proper processing, particularly when used in extrusion cooking. It has been used in nutrition intervention projects in Asia, Latin America, and Africa, transforming whole soy beans into weaning foods, instant gruels, and meat-like chunks in the food processing industry (Osundahunsi, 2006) [17].

Hot extrusion snacks involve thermal, pressure and mechanical shear which results in various composite of ingredients and also engages in physio-chemical parameters like texture, structure, expansion of the products. The product quality depends on the extrusion variables like barrel temperature, screw speed, feed moisture content, die diameter, feed rate (Sahu *et al.*, 2022) [23]. Hence, the present study was design to examine the physical and functional properties of jowar-based extruded snacks.

## Materials and Methods

**Raw Materials:** Jowar, corn, roasted bengal gram, soy flour was procured from the local market.

**Flour preparation:** Jowar grains and corn are cleaned in pre cleaner and milled into flour separately. Flours sieved in the 60mesh sieve to get fine flour and store at room temperature for further use.

**Preparation of extruded snacks:** To develop extruded snacks jowar flour: corn: soy flour: roasted bengal gram flour was taken in proportion of 50: 30: 15: 5 respectively. The samples were mixed thoroughly to get a homogenous mixture and then shifted to a batch mixer to blend the samples by adding the required amount of water to adjust the feed moisture content to 15%, then fed into the hopper to extrude the material. A co-rotating twin screw extruder (Model: KK SFE-65, Make: KK life sciences, Chennai, India) with a capacity of 50 kg/h was used to extruded the sample. The processing parameters used for extruding the material was 55 ºC (heater zone I), 75 ºC (heater II), and 120ºC (heater III), main screw speed (1320 rpm), feeder speed (900 rpm), the cutter speed (1140 rpm) and exit diameter of the die was 4 mm.

### Process parameters

The moisture content of flours and feed was analysed by the flour moisture analyser. The average of three values were considered.

**Mass flow rate (MFR):** The mass flow rate was expressed in grams per second. The extrudates were collected in a polythene bag for a particular time, cooled in a bag, and weighed (Naveena and Singh, 2021) [15].

$$\text{Mass flow rate (g/sec)} = \frac{\text{Weight of collected extrudates (g)}}{\text{Time taken to collect the extrudates } (sec)}$$

**Physical parameters:** Physical parameters, including specific length, expansion ratio, sectional expansion index, bulk density, tap density and true density were assessed for the developed extruded snacks.

**Specific length:** Ten extrudates from the extruded mass were randomly selected, and measured the length of the extrudate by using a vernier calliper. The average length of the extruded sample was determined. It was measured by using the following formula (Singh *et al.*, 2015) [25].

$$\text{Specific length (mm/g)}: \frac{\text{Length of extrudate}}{\text{Weight of extrudate}}$$

**Sectional expansion index (SEI):** Ten extrudates from the extruded mass were randomly selected, then measured the diameter of the extrudate by die diameter. It was calculated as the square of the extrudate diameter to die diameter (Da Silva *et al.*, 2014) [6].

$$\text{SEI} = \left(\frac{\text{Diameter of extrudate}}{\text{Die diameter}}\right)^2$$

**Tap density:** The powdered extruded sample were filled into the measuring cylinder (50 ml) up to 20 ml by tapping 5-10 times. Then weighed the filled 20 ml sample (Deshpande and Poshadri, 2011) [7].

$$\text{Tap density (g/cc)} = \frac{\text{Weight of 20 ml sample}}{\text{Volume of the sample(20 ml)}}$$

**True density:** True density was calculated by weighing 2 grams of grounded extruded sample into a measuring cylinder by filling it with toluene, and the true density was determined by measuring the rise in toluene content in the cylinder (Verma and Sharma, 2025) [33].

$$\text{True density} = \frac{\text{Weight of ground extruded sample (g)}}{\text{Rise in toluene level (ml)}}$$

**Bulk density (BD):** Bulk density was calculated by measuring the weight, diameters and length of the extrudate by using the vernier calliper (Asif *et al*., 2024) [2].

$$\text{BD} = \frac{4m}{\pi D^2 L}$$

where,
m = weight of the extrudate (g)
D = diameter of extrudate (cm)
L = length of extrudate (cm)

**Expansion ratio:** The ratio of the extrudates diameter to the die diameter. The average of random ten extrudates were measured by using the vernier calliper (Jacquet *et al*., 2025) [11].

$$\text{Expansion ratio (ER)} = \frac{\text{Extrudate Diameter (mm)}}{\text{Die Diameter (mm)}}$$

### Arithmetic mean diameter (AMD)

The arithmetic mean diameter of extrudates were calculated by the given equation below (Qadir and Wani, 2023) [20].
$AMD = (L + W + T)/3$

### Geometric mean diameter (GMD)

The equation given below is used to calculate the geometric diameter of extrudates (Qadir and Wani, 2023) [20].
$GMD = (L \times W \times T)^{1/3}$

### Equivalent mean diameter (EMD)

The equivalent mean diameter was determined by following equation (Qadir and Wani, 2023) [20].
$ED = [L\,(W+T)^2/4]^{1/3}$

### Functional parameters

**Water absorption index (WAI) and water solubility index (WSI):** one gram of ground extrudate sample was dispersed in 10 ml of distilled water, to break any lumps, stirred with a glass rod, kept for 30 minutes at room temperature, and then centrifuged at 3000 rpm for 15 minutes. The supernatant was decanted into a petri dish. The

WAI was calculated as the remaining sediment that settled at the bottom of the centrifuge tube by the weight of the original dry sample. The WSI is determined as the weight of the dry solid of supernatant, which was expressed as a percentage of the dry sample weight (Pardhi *et al.*, 2019) [18].

$$WAI = \frac{\text{Weight of sediment(g)}}{\text{Weight of dry extruded sample(g)}}$$

$$WSI\ (\%) = \frac{\text{Weight of dissolved solid in supernatent}}{\text{Weight of dry extruded sample}} \times 100$$

**Water holding capacity (WHC):** WHC is determined as 1 g of ground extruded sample powder was weighed in centrifuge tubes. In each sample, 10 ml of distilled water was added and the sample was mixed. The sample was kept at room temperature for 30 minutes, and allowed to rehydrate overnight in the remaining water. The sample was centrifuged at 3000 rpm for 15 minutes. Then, the supernatant was decanted carefully and the sample weight was recorded (Deshpande and Poshadri, 2011) [7].

$$WHC = \frac{\text{Wet extrudate weight (g)} - \text{Dry extrudate weight (g)}}{\text{Dry weight of sample (g)}} \times 100$$

### Sensory evaluation
The developed extruded samples were subjected to sensory evaluation was conducted with semi-trained panel of 15 members at Post Graduate & Research Centre, Professor Jayashankar Telangana Agricultural University. All the samples were coded by using the four digital random coded values and served. They were provided water and guided to rinse with water between the samples. The sample were evaluated for sensory properties like appearance, colour, flavour, texture, crispness and over all acceptability by using a 9-point hedonic rating scale (Meilgaard *et al.*, 1999) [13]. The acceptability index was calculated with the obtained mean scores (Arruda *et al.*, 2016) [1].

**Statistical analysis:** Mean and standard deviation was calculated for the extrudates and the mean difference was analysed (Snedecor and Cochran, 1983) [26].

## Results and Discussion
### Process parameters
The process parameters that were measured for both type of extruded samples are presented in Table 1 and the percentage difference in measured parameters in experimental sample when compared with control sample is illustrated in Figure 1. The flour moisture content of CMAK was 7.32±0.98% and it was 7.83±0.98% in JCSR (Table 1). There was 5.87% increase in flour moisture content in JCSR when compared with CMAK (Fig. 1). The feed moisture content of CMAK was 14.64±0.03% and it was 16.83±0.23% in JCSR (Table 1). There was 14.95% increase in feed moisture content in JCSR when compared with CMAK as per Figure 1. The mass flow rate of CMAK was 12.5±1.17g/sec and it was 13.5±0.23g/sec in JCSR (Table 1). There was 8% increase in mass flow rate in JCSR when compared with CMAK (Fig. 1). The mass flow rate (MFR) elucidates the resistant flow made by the co-rotating screw and the pressure was developed by the restricted exit die (Sobowale *et al.*, 2021) [27] because the level of temperature decreased then the mass flow rate will increase (Singh *et al.*, 2015) [25].

**Table 1:** Mean values of process parameters of developed extrudates

| Process Parameters | CMAK | JCSR |
|---|---|---|
| Flour moisture% | 7.32±0.98 | 7.83±0.08 |
| Feed moisture% | 14.64±0.03 | 16.83±0.23 |
| Mass flow rate(g/sec) | 12.5±1.17 | 13.5±0.23 |

**Note:** Values are expressed in mean ± standard deviation of three determinations

**CMAK:** Extrudates with 100% corn flour
**JCSR:** Extrudates with 50% jowar flour, 30% corn flour, 15% soy flour, 5% roasted Bengal gram flour.

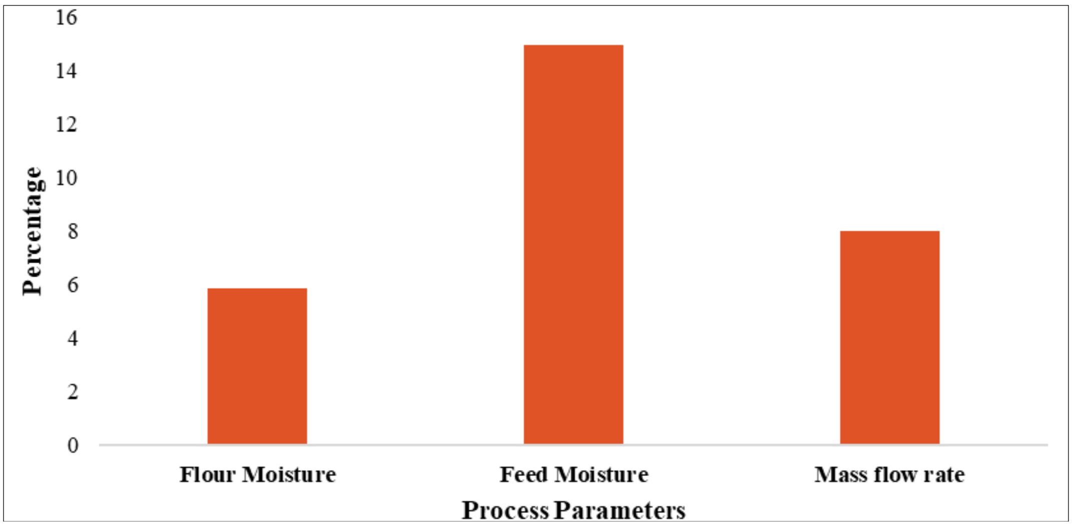



**Fig 1:** Percentage change in process parameters of JCSR when compared with CMAK

### Physical Parameters
The physical parameters that were measured for both type of extruded samples are presented in Table 2 and the percentage difference in experimental sample when compared with control sample in physical parameters was presented in Figure 2.

### Length (mm) and Diameter (mm)
The length of CMAK was 19.76±1.95 mm and it was 17.8±2.14 mm in JCSR (Table 2). There was 9.91% decrease in length in JCSR when compared with CMAK (Fig. 2). The diameter of CMAK was 16.64±1.05 mm and it was 11.4±1.34 mm in JCSR (Table 2). There was 31.49%

decrease in diameter in JCSR when compared with CMAK (Fig 2). Reddy *et al*. (2014) [21] reported that in black gram, roots based extrudates length range from 3.08±0.14 to 4.36±0.08 mm, and highest diameter (8.84±0.34) was observed for control product made from corn and black gram flour alone.

**Specific length (mm/g)**

The specific length of CMAK was 86.96±4.40mm/g and it was 105.59±12.78 mm/g in JCSR (Table 2). There was 21.42% increase in specific length in JCSR when compared with CMAK (Fig. 2). (Awol *et al*. (2024) [4] stated that the specific length increased with increase in barrel temperature although specific length decreased with increase in soy proportion up to 10%. Similarly, it was increased with increase in feed moisture content up to 11% by Singh *et al*. (2015) [25] with incorporation of soy flour (20%) and results show that high specific length was obtained at 15% moisture content and followed by 85 ºC and 95 ºC temperature. Specific length was influenced by moisture content and temperature.

**Expansion ratio (mm/mm)**

The expansion ratio of CMAK was 4.16±0.26mm/mm and it was 3.12±0.63mm/mm in JCSR presented in (Table 2). There was 25% decrease in expansion ratio in JCSR when compared with CMAK (Fig 2). It was may be the screw speed affects the expansion ratio. Attenborough *et al*. (2023) [3] developed jackfruit cornmeal based extrudates and reported that expansion ratio range from 0.6 to 2.8 for ripe jack fruit and unripe jackfruit has 0.6-2.4mm/mm. Increasing the screw speed for ripe and unripe jackfruit extrudates showed an increase in the ER. The ER was varied from 3.861 to 4.603 mm/mm in squid and millet based extrudates and also observed that expansion ratio and protein content have negative relationship of the extrudates which was observed by Ganesan *et al*. (2021) [9].

**Table 2:** Mean values of physical parameters of developed extrudates

| Physical parameters | CMAK | JCSR |
|---|---|---|
| Length(mm)* | 19.76±1.95 | 17.8±2.14 |
| Diameter (mm)* | 16.64±1.05 | 11.4±1.34 |
| Specific length (SL)* | 86.96±4.40 | 105.59±12.78 |
| Expansion ratio (ER)* | 4.16±0.26 | 3.12±0.63 |
| Bulk density (BD)* | 1.63±0.53 | 0.52±0.21 |
| SEI* | 17.36±2.17 | 8.22±1.93 |
| Tap density (g/cc) | 0.60±0.01 | 0.35±0.01 |
| True density (g/ml) | 0.09±0.00 | 0.06±0.00 |
| AMD* | 17.97±1.12 | 12.72±1.05 |
| GMD* | 17.90±1.09 | 11.95±1.19 |
| EMD* | 17.91±1.09 | 12.22±1.09 |

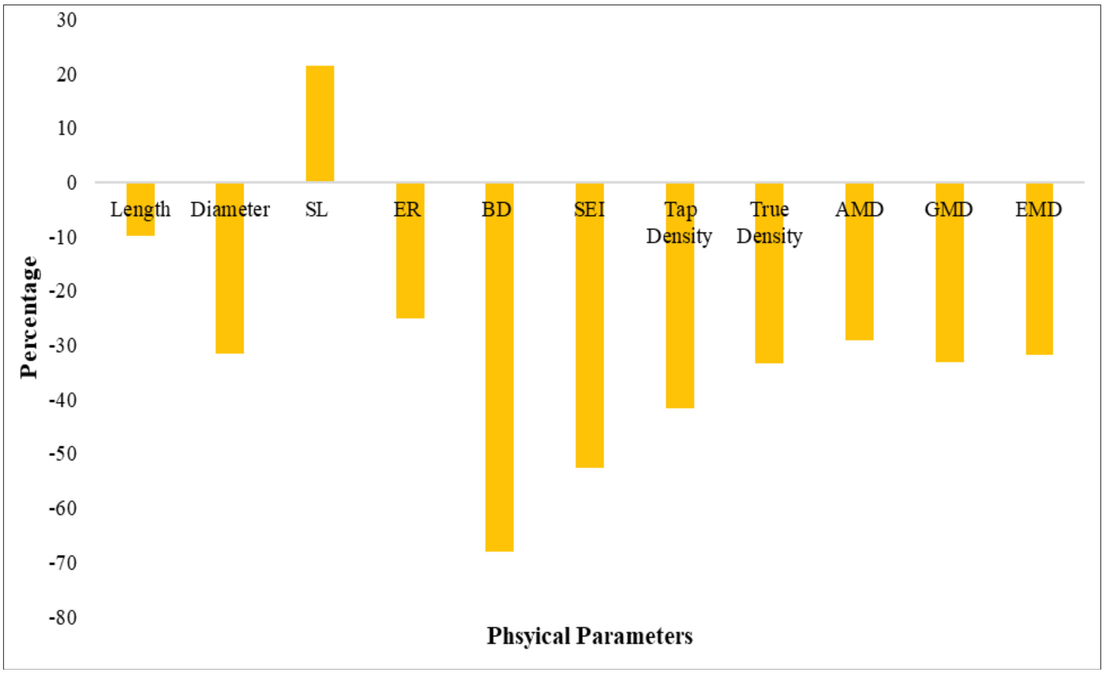
**Note:** Values are expressed in mean ± standard deviation of three determinations

(*) values are expressed in mean ± standard deviation of ten determinations

**CMAK:** Extrudates with 100% corn flour

**JCSR:** Extrudates with 50% jowar flour, 30% corn flour, 15% soy flour, 5% roasted bengal gram flour.

SL = Specific length, ER = Expansion ratio, BD = Bulk density, SEI = Sectional Expansion Index, AMD = Arithmetic mean diameter, GMD = Geometric mean diameter, EMD = Equivalent mean diameter.




**Note:** SL = Specific length, ER = Expansion ratio, BD = Bulk density, SEI = Sectional Expansion Index, AMD = Arithmetic mean diameter, GMD = Geometric mean diameter, EMD = Equivalent mean diameter.

**Fig 2:** Percentage change in Physical Parameters of JCSR when compared with CMAK

**Bulk density (g/cm$^3$)**

The bulk density of CMAK was 1.63±0.53g/cm$^3$ and it was 0.52±0.21g/cm$^3$ in JCSR (Table 2). There was 68.09% decrease in bulk density in JCSR when compared with CMAK (Fig. 2). BD observed by Vora *et al*. (2025) [34] was 0.049 to 0.56 g/cm3 which decreased with an increase in feed moisture content up to 15.15% and it depend on screw speed. Naveena and Singh (2021) [15] determined BD of samples of blend ratio 60% sorghum, 15% Bengal gram, 255 barely composition had 0.08 to 1.19 g/cm3 at 16% feed moisture and 160ºC temperature and 160 rpm, BD has effect on process variables such as barrel temperature, moisture content, screw speed and blend ratio.

**Sectional expansion index (SEI)**

The sectional expansion index (SEI) of CMAK was 17.36±2.17mm/mm and it was 8.22±1.93mm/mm in JCSR (Table 2). There was 52.64% decrease in sectional expansion index (SEI) in JCSR when compared with CMAK (Fig. 2) was due to raw material composition. Singh *et al*. (2015) [25] developed soybean blended extrudates has the SEI initially increased up to 15 -20% blend ratio of soybean and then decreased, it's highly related to moisture content and blend ratio. The SEI is oppositely related to the expansion of the product where energy is increased due to the elastic gelatinized starch networks (Stojceska *et al*., 2008) [29]. SEI values were ranged from 4.54 to 35.33 of carioca bean based extrudates increase in water content with applied heat stimulates the gelatinization of the material (da Silva *et al*., 2014) [6].

**Tap density (g/cc)**

The tap density of CMAK was 0.60±0.01g/cc and it was 0.35±0.01g/cc in JCSR (Table 2). There was 41.66% decrease in tap density in JCSR when compared with CMAK (Fig. 2). Deshpande and Poshadri. (2011) [7] observed the tap density of foxtail based extruded samples decreased due to the composite of flours of samples has range from 0.34 t0 0.37 g/cc. Similar results were type of reports given by Shadan *et al*. (2014) [24] the tap density was highest in corn based extrudates was high (0. 56 ± 0.04) followed by other formulations it is due to the raw materials, composition and the process conditions.

**True density (g/ml)**

The true density of CMAK was 0.09±0.00g/ml and it was 0.06±0.00g/ml in JCSR (Table 2). There was 33.33% decrease in true density in JCSR when compared with CMAK (Fig. 2). Kashinath *et al*. (2020) [12] found that finger millet and foxtail based composite extrudates has 0.25 g/m3 of true density. Similar way true density of 125.94 kg/m$^3$ was observed by Verma and Sharma. (2025) [33] of extrudate developed by moringa leaf powder. In the same way the true density for the millet flours of finger millet and pearl millet flours were 1.36±0.09 and 1.69±0.29 respectively observed by Gull *et al*. (2015) [10].

**AMD, GMD and EMD**

The arithmetic mean diameter (AMD) of CMAK was 17.97±1.12 mm and it was 12.72±1.05 mm in JCSR (Table 2). There was 29.21% decrease in arithmetic mean diameter (AMD) in JCSR when compared with CMAK (Fig. 2). The geometric mean diameter (GMD) of CMAK was 17.90±1.09 mm and it was 11.95±1.19 mm in JCSR (Table 2). There was 33.24% decrease in geometric mean diameter (AMD) in JCSR when compared with CMAK (Fig. 2). The equivalent mean diameter (EMD) of CMAK was 17.91±1.09 mm and it was 12.22±1.09 mm in JCSR (Table 2). There was 31.76% decrease in equivalent mean diameter (EMD) in JCSR when compared with CMAK (Fig. 2). These mean diameters are indicating that the amount of the extrudate were puffed at the observed temperature (120 ºC and 140 ºC). The mean diameters are depending on the processing conditions include feed moisture, barrel temperature and feed composition. In all three AMD, GMD and EMD the mean values (Table 4) obtained highest for the CMAK sample and reduced diameters were obtained in JCSR samples. Sabar *et al*. (2020) [22] observed that the average diameter values of AMG, GMD and EMD were observed in sorghum grains increase with an increase in moisture content, the values of AMD, GMD and EMD were from 3.38 to 3.53 mm, 3.20 to 3.53 mm and 4.11 to 4.51 mm respectively. Similar reports were observed by Qadir and Wani, (2023) [20] in Rice grains.

**Functional parameters**

The functional parameters that were measured for extruded samples are presented in Table 3 and the percentage change in functional parameters of experimental sample when compared with control sample is illustrated in Figure 3.

**Water absorption index (WAI)**

The water absorption index (WAI) of CMAK was 5.86±0.14 g/g and it was 4.17±0.58 g/g in JCSR (Table 3). There was 28.83% decrease in water absorption index (WAI) in JCSR when compared with CMAK (Fig. 3). WAI decreases with increase in composition, moisture content and screw speed in the same way WAI increase with increase in barrel temperature Yousf *et al*. (2017) [35]. The CMAK sample WAI was increased with increase in barrel temperature (140 ºC). Verma and Sharma, (2025) [33] reported that the process parameters like feed proportion, screw speed and barrel temperature showed positive coefficient with WAI in composite flour made with broken rice, soy meal, moringa leaf powder (70: 21.25 :8.75).

**Water solubility index (WSI)**

The water solubility index (WSI) of CMAK was 17.55±1.38% and it was 25.15±1.18%in JCSR (Table 3). There was 43.3% increase in water solubility index (WSI) in JCSR when compared with CMAK (Fig. 3). WSI was increased in JCSR sample compare to control samples it may be the expansion of the product and effect of process conditions of feed moisture, barrel temperature, screw speed and feed composition. The extrudates has WSI ranging from 6.20% to 11.20%, in this way water solubility index of extrude products are decreased with increase in feed moisture content stated by Vora *et al*. (2025) [34]. In accordance given by Attenborough *et al*. (2023) [3] observed that WSI of extrudate decreased as the particle size increased by increasing the surface area; the ripe jackfruit sample has high WSI compare the unripe and cornmeal sample. Therefore, it stated that high water-soluble fraction for ripe jackfruit might be due to the increased sugar content of ripe jackfruit. The highest WSI of extrudates are 11.95% in 5% soybean, 12% feed moisture, and 135 ºC barrel temperature however, the lowest value of WSI has 7.96% of the sample 17.6% soybean, 11% feed moisture, and 130 ºC barrel temperature observed by Awol *et al*. (2024) [4].

**Water holding capacity (WHC)**

The water holding capacity (WHC) of CMAK was 464.56±3.68% and it was 342.28±64.39% in JCSR (Table 3). There was 26.32% decrease in water solubility index

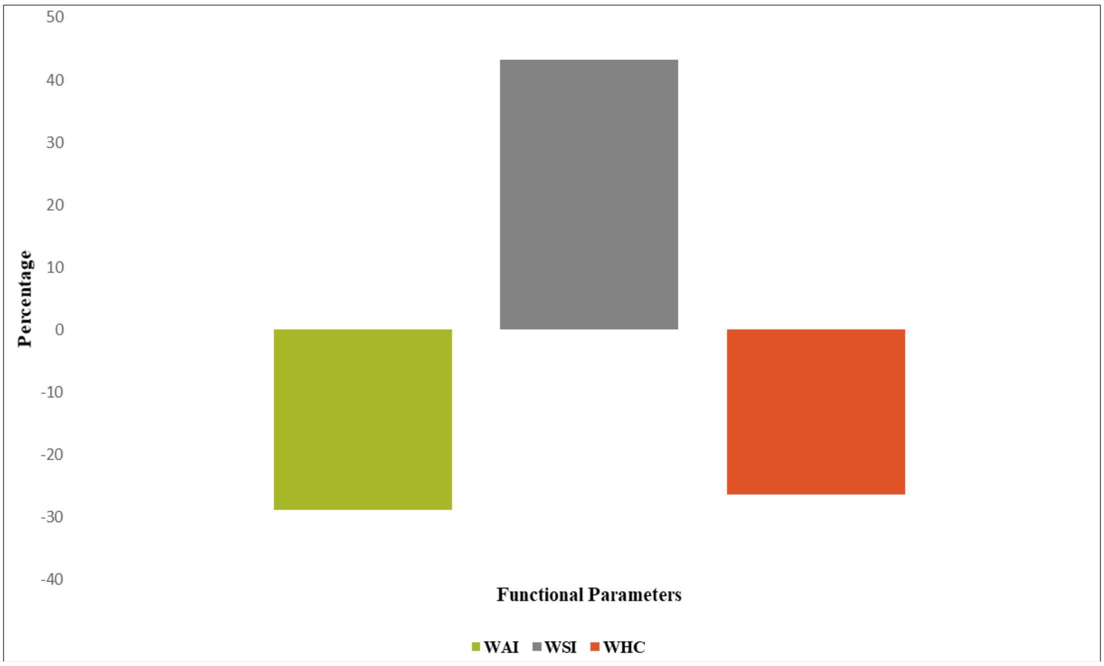
(WSI) in JCSR when compared with CMAK (Fig. 3). WHC measures the amount of water absorbed by the product, the JCSR has decreased holding capacity compare to the CMAK it is due to feed composition and the barrel temperature. Musundire *et al*. (2021) [14] observed the instant porridge has 60.1% of WHC which is influenced by the extrusion conditions like shear force that help to molecular breakdown of food particles. Similar results, were given by Shadan *et al*. (2014) [24]. Water holding capacity has influenced by two factors that composition and the thermal & mechanical effect which influence more protein modifications stated by Nguyen *et al*. (2015) [16]. Sukumar and Athmaselvi (2019) [30] stated that water holing capacity was affected by the process parameters of extruded snacks.

**Table 3:** Mean values of functional parameters of developed extrudates

| Functional parameters | CMAK | JCSR |
|---|---|---|
| WAI | 5.86±0.14 | 4.17±0.58 |
| WSI | 17.55±1.38 | 25.15±1.18 |
| WHC | 464.56±3.68 | 342.28±64.39 |

**Note:** Values are expressed in mean ± standard deviation of three determinations

**CMAK:** Extrudates with 100% corn flour
**JCSR:** Extrudates with 50% jowar flour, 30% corn flour, 15% soy flour, 5% roasted bengal gram flour.
WAI = Water Absorption Index, WSI = Water Solubility Index, WHC = Water Holding Capacity




**Note:** WAI = Water Absorption Index, WSI = Water Solubility Index, WHC = Water Holding Capacity

**Fig 3:** Percentage change in functional parameters of JCSR when compared with CMAK

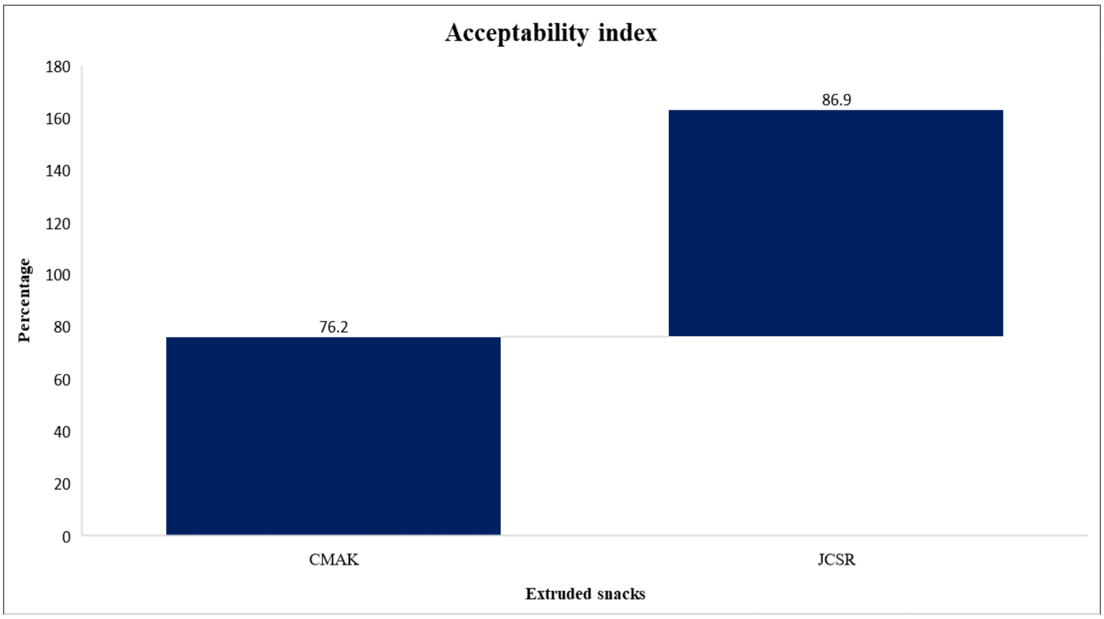
## Sensory evaluation

The sensory evaluation scores that were measured for both type of extruded samples are presented in Table 4 and the acceptability index was calculated with mean values were illustrated in Figure 4. The appearance of CMAK was 8.06±0.70 and it was 7.60±0.91in JCSR (Table 4). The colour of CMAK was 8.00±0.84 and it was 7.66±0.72 in JCSR (Table 4). The flavour of CMAK was 7.86±0.83 and it 7.60±0.9 it was in JCSR (Table 4). The taste of CMAK was 7.86±0.74 and it 7.20±0.79 in JCSR (Table 4). The texture of CMAK was 8.13±0.51and it was 8.20±0.86 in JCSR (Table 4). The crispness of CMAK was 8.13±0.74 and it 8.20±0.56 it was in JCSR (Table 4). The overall acceptability of CMAK was 8.13±0.63 and it 8.30±0.72 it was in JCSR (Table 4). The percentage of the acceptability index of JCSR was 86.9% and CMAK was 76.2% as presented in Figure 4. The appearance, colour, flavour and taste were decreased when compare with the control sample (CMAK) as presented in (Table 4). The texture of CMAK was 8.13±0.51and it was 8.20±0.86 in JCSR (Table 4). The crispness of CMAK was 8.13±0.74 and it 8.20±0.56 it was in JCSR (Table 4). The overall acceptability of CMAK was 8.13±0.63 and it 8.30±0.72 it was in JCSR (Table 4). The sensory attributes of texture, crispness and overall acceptability was increased compared with CMAK. The acceptability index (AI%) of JCSR was 86.9% and CMAK was 76.2 which show the jowar extruded snacks were more acceptable than control sample (Fig. 3).

**Table 4:** Mean Sensory Scores of Developed Extruded Snacks

| Sensory evaluation | CMAK | JCSR |
|---|---|---|
| Appearance | 8.06±0.70 | 7.60±0.91 |
| Colour | 8.00±0.84 | 7.66±0.72 |
| Flavour | 7.86±0.83 | 7.60±0.91 |
| Taste | 7.86±0.74 | 7.20±0.79 |
| Texture | 8.13±0.51 | 8.20±0.86 |
| Crispness | 8.13±0.74 | 8.20±0.56 |
| Overall Acceptability | 8.13±0.63 | 8.30±0.72 |

**Note:** Values are expressed in mean ± standard deviation of fifteen determinations




**Note:** CMAK: Extrudates with 100% corn flour
JCSR: Extrudates with 50% jowar flour, 30% corn flour, 15% soy flour, 5% roasted Bengal gram flour.

**Fig 4:** Acceptability Index (AI%) of the Extruded Samples

## Conclusion

The jowar based extrudates were developed by using the composite blend of jowar flour, corn flour, soy flour and roasted Bengal gram in ratio of 50:30:15:5 respectively under the optimized processing conditions. The significant change was observed in specific length and WSI; however, the bulk density, tap density, WAI, and expansion ratio were reduced. The JCSR sample showed a high sensory acceptability. These findings suggest possibility of commercialization of the product in the market and meeting the consumer demands of ready-to-eat millet-based healthy snacks.

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