

**RESEARCH PAPER**

## Effect of Packaging Material and Storage Duration on the Quality of Tuber Crop based Extruded Products

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### ABSTRACT

In the present study, extrudates prepared from (arrowroot (10%), lesser yam (40%) and potato (50%) with twin screw extruder at extrusion temperature 130°C, screw speed 330 rpm and 10% moisture (7ml water:3ml Kokum Liquid Concentrate)) were used for the packaging and storage study of the extrudates. The 60 g extrudates were packed in 3 types of packaging materials i.e. aluminium foil (200 gauge), polyethylene (400 gauge) and polyester (160 gauge) and stored at ambient temperature up to 60 days. Then stored samples were evaluated at interval of 0, 10, 20, 30, 40, 50 and 60 days for nutritional properties like protein, fat, fiber, ash, moisture, carbohydrates and functional properties like expansion ratio, bulk density, water absorption index, water solubility index, hardness in order to study the storage stability of the product. It was found that there is no significant ( $p \leq 0.01$ ) effect of packaging material and storage durations on nutritional and functional properties of stored extrudates. Among the packaging materials studied aluminium foil (200 gauge) was the best packaging material to store the extrudates. Aluminium foil is the best packaging material to store the extrudates up to 60 days. The nutritional properties at the 60 days period were protein 2.70 %, fat 1.22 %, fiber 1.06 %, ash 1.83 %, carbohydrates 86.01 % and moisture 6.83 %. The functional properties of the extrudates at 60 days period in the aluminium foil is expansion ratio 3.09, bulk density 0.09 g/cm<sup>3</sup>, water absorption index 4.54 g/g, water solubility index 42.67 %, and hardness of extrudates 1658 g respectively. Extrudates can be stored in good condition in aluminium foil up to 2 months with better retention of nutritional and functional properties.

**Keywords:** Arrowroot flour, Lesser yam flour, Potato flour, Extrusion cooking, Packaging materials, Storage study, Nutritional and functional properties

The Indian snack food market is of the order of 400,000 tones. This wide range of products is categorized under Potato/Banana chips, Namkeen and Fun Foods. The snack market in India has grown by leaps and bounds in the past two decades and is reported to be growing at 7 to 8 per cent annually. A snack is a portion of food often times smaller than that of a regular meal that is generally eaten between meals. Consumers demand is increasing for whole grain snacks that are low in fat, high in

protein, high in dietary fiber and deliver balanced nutrition. Extrusion technology has taken the snack food category far from the domain of the potato chip and pretzel that dominated it for decades. Extrusion processing is popular in the food industry and can

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efficiently create novel products that might not be possible with other processing methods (Cisneros and Kokini, 2002) such as snacks and ready to eat foods. Extrudates are microbiologically safe, can be stored for long periods because of low moisture food and can be kept without need for refrigeration and requires less labor for handling and less packaging materials and storage space (Filli and Nkama, 2007).

Arrowroot (*Maranta arundinaceae*) is straight herbaceous plant belonging to *Marantaceae* family, commonly known as 'West Indian Arrowroot' (Pandey, 2007). It is a low perennial herbaceous plant with thick, fleshy and creeping roots and long white fibers and is a good source of flour. Arrowroot starch has a high digestibility and wide food applications such as convalescent foods, weaning food and biscuits. In addition to this, the starch also can be used as a thickener for sauces and gravies or used for making clear glazes for fruit piece. This tuber has been used as a traditional healthy diet in many Asian countries, including Indonesia due to the presence of a soluble dietary fiber *glucomannan*. This fiber has been claimed to prevent some diseases such as diabetes, obesity, hyperlipidemia, and cardiovascular diseases (Aprianita, 2010). It can be substituted for corn starch. This powder is a source of one of the purest form of natural carbohydrates. Arrowroot powder has cooling effects on the body. Arrowroot starch is commercially underexploited tuber starch having potential digestive and medicinal properties and has been subjected to extrusion cooking for prepared extrudates using a twin screw food extruder (Anonymous, 2014).

Lesser yam (*Dioscorea*) belongs to the family of *Dioscoreaceae*. Yams are second to cassava as the most important tropical root crop. Yams are a staple crop in many parts of Africa and Southeast Asia. Yams are mainly grown for direct human consumption and are marketed as fresh produce in all the growing regions. Yam is considered to be the most nutritious of the tropical root crops (Wanasundera and Ravindran, 1994). It contains approximately four times as much protein as cassava and is the only major root crop

that exceeds rice in protein content in proportion to digestible energy (Bradbury and Holloway 1988). The amino acid composition of yam protein is suboptimal in sulfur-containing amino acids (cysteine and methionine), but the overall rating for essential amino acids is high and superior to sweetpotato (Splittstoesser *et al.* 1973; Bhandari *et al.* 2003). Yam is also a good source of vitamins A and C, and of fibre and minerals. Its relatively low calcium content is related to low concentrations of calcium oxalate, an antinutritional factor (Bradbury and Holloway, 1988). It is also low in the antinutrients phytate (Wanasundera and Ravindran, 1994) and trypsin inhibitor (Bradbury and Holloway, 1988).

Potato (*Solanum tuberosum*) is a starchy crop used as materials to many types of food and snack's production. It consists of 63-83% moisture content, 13-30% carbohydrate, 0.7-4.6% protein and 0.44% ash (Puttongsiri *et al.* 2012). It is made from minced cooked potato or mix with ingredients such as butter and salt. The potatoes are rich in protein and vitamin B which can help to enhance the physical conditions and improve the memory ability and clear thoughts. It is a nutritious food containing practically all the essential dietary constituents. Like cereals, carbohydrates are the major constituents of potato. Besides, it contains essential nutrients such as proteins and minerals like calcium, phosphorus and iron, and vitamins (B1, B2, B6 and C). Potatoes can even be exported to some of the European countries during March-May when fresh potatoes are not available in these countries (Pandey, 2007).

Extrusion cooking is a high-temperature; short-time (HTST) technology applied in many food production processes and considered as a continuous cooking, mixing, and forming process with low cost and high efficiency (Ryu *et al.*, 1993; Abd El-Hady *et al.* 1998; Ding *et al.* 2005.) Extruder is a thermodynamic unit which involves the combination of heat, pressure and mechanical shear. The process is achieved by screw and barrel tube mechanism. Feed material in granular form are fed into the extruder barrel, then screw, then convey the material and compress and

work in shear to transform the granular feed material into a semi solid plasticized mass the food is then extruded through an interchangeable die and cut at die either by rotating knives or subsequently by guillotine knives to form a variety of shapes. During extrusion, the cooking temperature could be as high as 180-190 °C; residence time is usually 20-40 seconds. The results of cooking the food ingredients during extrusion are gelatinization of starch, denaturation of protein, inactivation of raw food enzymes, destruction of naturally occurring toxic substances, diminishing of microbial counts in the final product. Advantages of food extrusion are versatility, high productivity, low cost, product shapes, high product quality, and energy efficiency, production of new foods, and no effluents or waste (Balfour *et al.* 2014).

The packaging of food is one of the prime requisites to improve and monitor the producer to consumer food production system. It forms an integral part of manufacturing process providing the link between the processor and the consumer. In fact, it plays a dominant role in the total food manufacturing activity and in marketing sector. Snack food have to be packed in attractive packaging so as to given impression of wholesomeness and freshness to increase sales appeal and it should be hygienic. With growing concern of diet, weight control and general health, government bodies are recommending to the peoples and making a conscious effort to eat healthier, natural snacks such as fruit, vegetable, nuts and cereal grains while avoiding high-calorie, low-calorie nutrient junk food (Saurabh *et al.* 2013). Packaging is a means of providing the correct environmental conditions for food during storage and the choice of materials for packaging depends on the nature of the product, storage duration and handling conditions (temperature, humidity, risk of physical deterioration) and other environmental factors (Daramola *et al.* 2010). To store extrudates for maximum period, it requires good packaging material to extend the shelf life of the extrudates by better protection from hazards during storage.

## MATERIAL AND METHODS

### Raw material

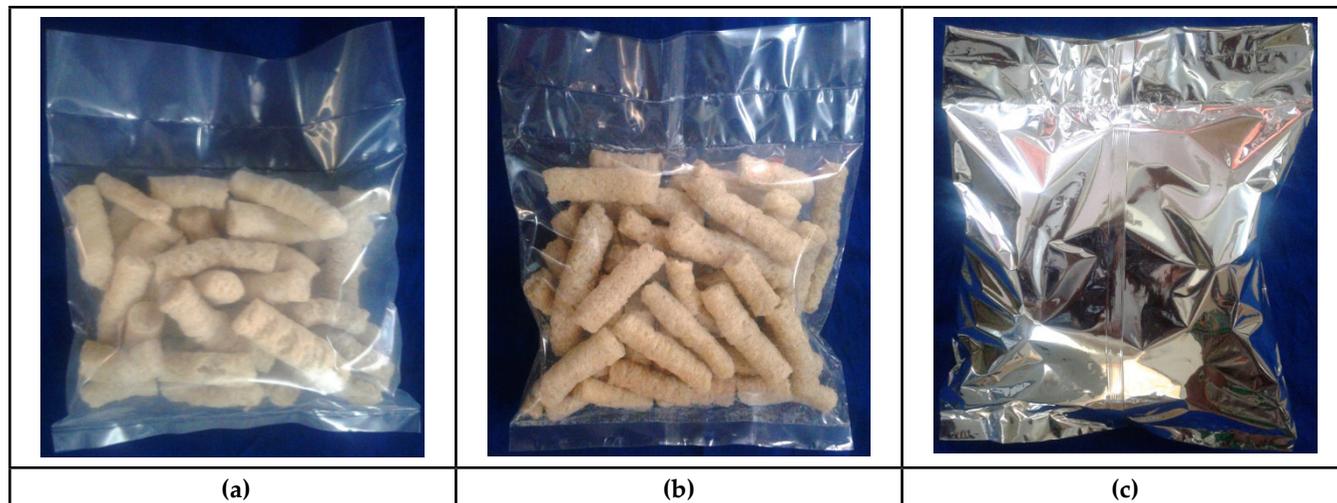
Raw material viz Arrowroot, lesser yam material required for experimentation was procured from university farm, Dr. B.S.K.K.V. Dapoli. Potatos required for experimentation was procured from Dapoli market. Both three types of tubers were collected for making flour.

The packaging and storage study experiments were conducted in NAIP Lab of Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology Dapoli. The development of the extruded from arrowroot, lesser yam potato flours were done at Extrusion Laboratory, Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology Dapoli. The nutritional and functional properties evaluation of the developed extruded were done in the Department of Agricultural Chemistry and Soil Science, College of Agriculture and NAIP Lab of Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology Dapoli.

The best treatment obtained from sensory analysis was used for the packaging and storage study of arrowroot, lesser yam and potato based extruded products. The best treatment obtained during sensory analysis was T2 which content proportion of Arrowroot (10%): Lesser yam (40%): Potato (50%) at extrusion temperature was 130°C and screw speed was 390 rpm. 60 g of best treatment extruded sample was taken in three different packaging materials i.e. Polyethylene (400), Polyester (160) and Aluminium Foil (200). The details of packaging materials are given in Table 1. Fig. 1 (a), (b) and (c) shows the packaging materials i.e. Polyethylene, Polyester and Aluminium Foil respectively, used for packaging and storage of arrowroot, lesser yam and potato based extruded products for 2 months. Table 1 shows the specifications of packaging material for storage of extrudates.

**Table 1:** Specifications of packaging material for storage of extrudates

Sl. No.	Packaging material	Size	Gauge	Capacity
1	Polyethylene	12 cm × 10 cm	400	60 g
2	Polyester	12 cm × 10 cm	160	60 g
2	Aluminium Foil	10 cm × 8 cm	200	60 g


**Fig. 1:** Packaging materials used for storage of extrudates; (a) Polyethylene, (b) Polyester and (c) Aluminium Foil

60 g of extruded sample was filled separately in polyethylene, polyester and aluminium foil and sealed properly. These packets were kept at ambient condition up to 6 weeks. The stored samples were analyzed every 10 days interval up to 2 months. The observations for the nutritional and functional properties of stored sample were taken during 7 durations (0, 10, 20, 30, 40, 50 and 60 days) i.e. total number of samples for all the trials were, 7 durations × 3 packaging materials × 3 replications = 63 samples of extrudates kept for storage study. The nutritional properties like protein, fat, fiber, ash, moisture content and carbohydrate for the stored samples were determined for each storage duration i.e. 0, 10, 20, 30, 40, 50 and 60 days. The functional properties like expansion ratio, bulk density, water absorption index, water solubility index, hardness and yellowness index for the stored samples were determined for each storage duration i.e. 0, 10, 20, 30, 40, 50 and 60 days.

The functional and nutritional properties of stored extruded samples were measured by following methods.

#### Nutritional Properties

The extruded prepared using the flour combinations i.e. arrowroot (10%): lesser yam (40%): potato (50%), moisture (10% i.e. water (7ml): kokum liquid concentrate (3ml)), temperature of extrusion 130°C and screw speed 390 rpm. The extrudates prepared as per the above treatment combination were stored for 2 months and used for the nutritional analysis duration of 10 days. The extrudates prepared using above mentioned treatment combinations was grounded to an average particle size of 1.30 $\mu$ . The extrudate powders were equilibrated to 8% (db) MC in desiccators by using the saturated solution of salt NaCl at the atmospheric temperature to maintain its RH 75%. These flour samples were used as extruded sample flour. The nutritional analysis i.e. protein, fat, fibre, ash, moisture and carbohydrates content of the

stored extruded flour samples were determined as per the following standard procedures.

### 1. Moisture content

The initial moisture content of extrudates flour was determined by using hot air oven method (AOAC, 2010). The 10 g flour was taken in the moisture box. The moisture box was kept in hot air oven at  $105^{\circ}\text{C}\pm 1$  for 24 h. The final weight of flour after 24 h was recorded. The experiment was recorded 3 times for each storage duration (0, 10, 20, 30, 40, 50 and 60 days). The average moisture content reading is reported by using following Eq. (1);

$$\text{Moisture Content (db) \%} = \frac{M_2 - M_3}{M_3 - M_1} \times 100 \quad \dots(1)$$

Where:

$M_1$ =Weight of moisture box, g;

$M_2$ =Weight of moisture box +sample before drying, g; and

$M_3$ =Weight of moisture box+ bone dried sample, g.

### 2. Protein

The protein content of extrudates flour was measured by Microkjhdhal method (Ranganna, 1986). Around 0.25 g flour was taken for the analysis. 15 ml  $\text{H}_2\text{SO}_4$  was added in the flour and solution was allowed to predigest for 14 h (overnight). After digestion of sample 5 ml  $\text{H}_2\text{O}_2$  was added to it and mixture was shaken up to colour of sample change to colour less sample. Colour less sample was makeup up to volume 25 ml. The makeup sample (25 ml) was taken as volume of aliquot. After digestion procedure was complete, the sample was allowed for distillation was done in automatic distillation unit provided with receiver flask contained 20 ml boric acid indicator. The mixture of 10 ml colourless sample solution (aliquot) and 10 ml water was taken for distillation with flushing the NaOH as 25 ml in nitrogen distillation unit. The outlet tube of distillation unit assembly was properly submerged into the indicator. Mixing chamber of the assembly was heated for 6 minute or until the colour of indicator solution was changed

from pink to green. The experiments were replicated for 3 times times for each storage duration (0, 10, 20, 30, 40, 50 and 60 days). The distillate sample was titrated against 0.01N  $\text{H}_2\text{SO}_4$  and % protein content was calculated by Eq. (2);

$$\% \text{ Protein} = \frac{(\text{Sample titre} - \text{Blank titre}) \times \text{Normality of } \text{H}_2 \text{ 2SO}_4 \times 0.014 \times \text{vol.of aliquot} \times 6.25 \times 100}{\text{Weight of sample taken}} \quad \dots(2)$$

### 3. Fat

Fat content of extrudates flour was determined using soxhlet fat extraction system (AOAC, 2010) by Soxhlet apparatus (Make: Elico, Hyderabad). In this method, initially weight of empty flask was weighed. 2 g flour was wrapped in filter paper. The sample with filter paper was kept in siphoning tube and condenser was fixed above it and siphoned for 9-12 times with the petroleum ether in soxhlet apparatus. After removing assembly, evaporation of petroleum ether was allowed by heating round bottom flask. Residue remained at the bottom of the flask and was reweighed with flask. The quantity of residue was determined as fat content of flour. The experiments were replicated for 3 times for each storage duration (0, 10, 20, 30, 40, 50 and 60 days). Fat content was calculated by using Eq. (3);

$$\% \text{ Fat content} = \frac{\text{Final wt.} - \text{Initial wt.}}{\text{Wt.of sample}} \times 100 \quad \dots(3)$$

### 4. Crude fibre

The fibre content of extrudates flour was determined from the fat free sample available in filter paper from fat extraction method (Ranganna, 1986). The filter paper and fat free residue was kept in the oven for  $105^{\circ}\text{C}$  for 5-6 hours. Around 2 g sample from oven was taken into 600 ml beaker and boiled; to it 200 ml of 1.25%  $\text{H}_2\text{SO}_4$  was added. The beaker containing solution was placed on hot plate for 30 minute. After heating residue from beaker was filtered through filter paper and rinsed beaker with 50 to 75 ml boiling

water for three times. The filtered residue from filter paper was dried by convective hot air drying for 2-3 h at  $130\pm 1^\circ\text{C}$ . The dried residue from convective hot air dryer was transferred to 600 ml beaker and boiled, 200 ml 1.25 % NaOH was added to it and boiled for 30 minutes on hot plate. After heating the residue from beaker was filtered through filter paper and rinsed beaker with 50 to 75 ml boiling water for three times. The filtered residue from filter paper was dried by convective hot air drying at  $130^\circ\text{C}$  for 2 h. The dried residue was weighed after cooling and weight was noted. The weighed residue was transferred to crucible in hot air oven and ignited for 30 minutes at  $600^\circ\text{C}$  and reweighed after cooled in dessicator and weight was recorded. The experiments were replicated for 3 times for each storage duration (0, 10, 20, 30, 40, 50 and 60 days). The fibre content of extrudates flours were calculated by Eq. (4);

$$\% \text{ Fibre} = \frac{\text{Weight of residue with crucible} - \text{weight of ash with crucible}}{\text{Weight of sample}} \times 100 \quad \dots(4)$$

### 5. Ash content

Ash content of extrudates flour was calculated using muffle furnace. Five gram of flour was taken in a crucible. Weight of crucible and flour was recorded and kept in muffle furnace at  $650^\circ\text{C}$  for 4-5 h till constant weight was achieved. It was observed for three constant readings. The crucible was cooled in desiccators and final weight of ash and crucible was recorded. The experiments were replicated for 3 times for each storage duration (0, 10, 20, 30, 40, 50 and 60 days). Ash content was calculated by using Eq. (5);

$$\text{Ashcontent, \%} = \frac{W_2 - W}{W_1 - W} \times 100 \quad \dots(5)$$

Where,

$W$  = weight of crucible, g;

$W_1$  = weight of crucible and flour, g; and

$W_2$  = weight of crucible with ash, g.

### 6. Carbohydrates

Carbohydrate content was determined by subtracting the total sum of protein, fibre, ash and fat from the total dry matter (Vengaiah *et al.* 2013). The carbohydrates were determined for extruded flour sample for each storage duration (0, 10, 20, 30, 40, 50 and 60 days). Carbohydrates were calculated by using Eq. (6);

$$\text{Carbohydrates} = 100 - (\text{protein} + \text{fat} + \text{fibre} + \text{ash} + \text{moisture content}) \quad \dots(6)$$

### Functional properties

The functional properties of extrudates are Expansion ratio, Bulk density, Water Absorption Index (WAI), Water Solubility Index (WSI), Colour and Hardness were determined as per the procedures described as below.

#### 1. Expansion ratio

The expansion ratio of extrudates was determined as per the procedure described by (Pathania *et al.* 2013). The ratio of the diameter of the extrudate and the diameter of the die was used to express the expansion of the extrudate. The diameter of the extrudate was determined as the mean of random measurements made with a Vernier caliper (0.01cm). The extrudates cut into 8-10 cm pieces. The diameter of extrudates were determined at 5 different locations along the length ( $d$ ) of extrudates and against  $90^\circ$  to that length ( $d'$ ) as given in Fig. 2. The average value of diameter (eq.(7)) at these 5 locations was reported as diameter of extrudates. The experiment was replicated 10 times at each storage duration (0, 10, 20, 30, 40, 50 and 60 days). The die diameter of extrudates was 5mm. Expansion ratio calculated by Eq. (8);

$$\text{Average value } (d_{avg}) = \frac{(d_1 + d'_1) + (d_2 + d'_2) + (d_3 + d'_3) + (d_4 + d'_4) + (d_5 + d'_5)}{10} \quad \dots(7)$$

$$\text{Expansion ratio} = \frac{\text{Average value } (d_{avg})}{\text{Die Diameter}} \quad \dots(8)$$

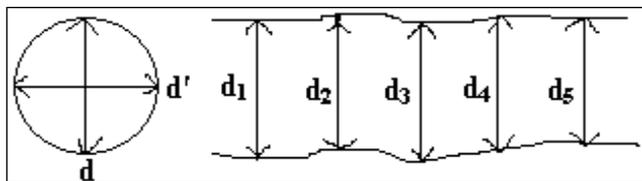


Fig. 2: Diameter of extrudates

## 2. Bulk density (g/cm<sup>3</sup>)

Bulk density (g/cm<sup>3</sup>) was calculated as per the procedure described by (Stojceska *et al.* 2008). Bulk density was calculated from the mass of extrudates, length of extrudates and average diameter ( $d_{avg}$ ) of extrudates from eq. (7) as described in eq. (9). Bulk density determined at each storage duration (0, 10, 20, 30, 40, 50 and 60 days). Bulk density (g/cm<sup>3</sup>) determined by using Eq. (9);

$$\frac{4m}{\pi \times d_{avg}^2 \times L} \quad \dots(9)$$

Where:

$m$  = Mass of extrudates, g;

$L$  = Length of extrudates, cm; and

$d_{avg}$  = Average diameter of individual extrudates, cm.

## 3. Water Absorption Index (WAI)

The WAI of extrudates were determined as per the procedure described by (Stojceska *et al.* 2008). The 1 g ground extrudate sample was suspended in 10 ml of water at room temperature for 30 min, the mixture is gently stirred during this period and then centrifuged at 3000 g for 15 min. The supernatant was decanted into an evaporating dish of known weight. The WAI was the weight of water obtained after removal of the supernatant per unit weight of original dry solids. The water absorption index (WAI) was calculated for each storage duration (0, 10, 20, 30, 40, 50 and 60 days). WAI calculated by using Eq. (10);

$$WAI = \frac{\text{Weight gain by gel,(g)}}{\text{Dry weight of extruded,(g)}} \quad \dots(10)$$

## 4. Water Solubility Index (WSI)

The WSI of extrudates were determined as per the

procedure described by (Stojceska *et al.*, 2008). WSI was determined as per procedure given in section 2.3.3. WSI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample. The water solubility index (WSI) was calculated for each storage duration (0, 10, 20, 30, 40, 50 and 60 days). WSI calculated by using Eq. (11);

$$WSI (\%) = \frac{\text{Weight of dry solid in supernatant}}{\text{Dry weight of extruded}} \times 100 \quad \dots(11)$$

## 5. Hardness of extrudates

The peak force as an indication of hardness was measured with Texture Pro CT V1.3 Build Texture Analyzer (M/s Brookfield Engineering Labs, Inc., USA) using TA3/100 probe. The test speed was 0.5 mm/s. The depth of penetration of probe in sample was 4 mm. Extruded sample was placed at the base of the sample holder of the texture analyzer. Trigger load was provided 5g. The force which was required to break the extruded sample was recorded as hardness of extruded. The equipment gives the force deformation characteristics of the extrudates by using Texture Exponent 32 software program (version 3.0).

## Statistical analysis

Statistical analysis of SE and CD values for nutritional properties of stored sample like protein, fat, fiber, ash, moisture and carbohydrates and functional properties of stored samples like expansion ratio, bulk density, water absorption capacity, water solubility index, hardness and yellowness index were determined for the packed extrudates in polyethylene, polyester and aluminium foil and stored for 0, 10, 20, 30, 40, 50 and 60 days was carried out by SAS 3.0. Recorded data were subjected to statistical analysis by "Analysis of variance" technique. ANOVA with single factor was done. The significant and non-significant treatment was judged with the help of F (variance ratio) table and t-test. The significant different between the means was tested against the critical difference at  $p \leq 0.01$ .

## RESULTS AND DISCUSSION

### Nutritional properties

#### 1. Protein content

Table 2 shows the effect of packaging material and storage duration on protein content of extrudates. The protein content decreased from 2.92 to 2.70 %, 2.92 to 2.46 % and 2.92 to 2.57 % in aluminium foil, polyethylene and polyester respectively. Table 8 (a) shows the ANOVA for change in protein content in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

Decrease in protein content with increase in storage period from 0-60 days is higher in polyethylene pouches than polyester and aluminium foil pouches for extruded. This decrease in protein content with increase in storage duration was not significant effect at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the protein content of the extrudates were non significant at  $p \leq 0.01$ . As the difference between means of protein content

of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant effect at  $p \leq 0.01$  from each other.

Protein content decreased with increase in storage durations. Similar findings were reported by Osundahunsi, 2006; Balfour *et al.* 2014; Saurabh *et al.* 2013, for extruded from soya bean with paintain flour blends, extruded fortified corn and snack food packed in combination film respectively.

#### 2. Fat content

Table 3 shows the effect of packaging material and storage duration on fat content of extrudates. The fat content decreased from 1.42 to 1.22 %, 1.42 to 1.15 % and 1.42 to 1.19 % in aluminium foil, polyethylene and polyester respectively. Table 8 (b) shows the ANOVA for change in fat content in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

Decrease in fat content with increase in storage period from 0-60 days is higher in polyethylene pouches than

**Table 2:** Effect of packaging material and storage duration on Protein content of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	2.92 <sup>a</sup>	2.87 <sup>a</sup>	2.84 <sup>a</sup>	2.81 <sup>a</sup>	2.75 <sup>a</sup>	2.70 <sup>a</sup>	2.70 <sup>a</sup>
2	Polyethylene	2.92 <sup>a</sup>	2.81 <sup>a</sup>	2.75 <sup>a</sup>	2.63 <sup>ba</sup>	2.57 <sup>a</sup>	2.52 <sup>a</sup>	2.46 <sup>ba</sup>
3	Polyester	2.92 <sup>a</sup>	2.83 <sup>a</sup>	2.82 <sup>a</sup>	2.78 <sup>b</sup>	2.64 <sup>a</sup>	2.60 <sup>a</sup>	2.57 <sup>b</sup>
SE		0.0262	0.0698	0.0804	0.0340	0.0698	0.0594	0.0348
CD at 1%		0.1176	0.3127	0.3603	0.1523	0.3128	0.2661	0.1561

Same letter are not significantly different ( $p \leq 0.01$ ).

**Table 3:** Effect of packaging material and storage duration on Fat content of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	1.42 <sup>a</sup>	1.41 <sup>a</sup>	1.39 <sup>a</sup>	1.35 <sup>a</sup>	1.33 <sup>a</sup>	1.29 <sup>a</sup>	1.22 <sup>a</sup>
2	Polyethylene	1.42 <sup>a</sup>	1.39 <sup>ba</sup>	1.36 <sup>a</sup>	1.33 <sup>a</sup>	1.26 <sup>a</sup>	1.21 <sup>a</sup>	1.15 <sup>a</sup>
3	Polyester	1.42 <sup>a</sup>	1.40 <sup>b</sup>	1.37 <sup>a</sup>	1.35 <sup>a</sup>	1.3 <sup>a</sup>	1.27 <sup>a</sup>	1.19 <sup>a</sup>
SE		0.0000	0.0046	0.0347	0.0150	0.0235	0.0263	0.0464
CD at 1%		0.0000	0.0208	0.1555	0.0674	0.1051	0.118	0.2081

Same letter are not significantly different ( $p \leq 0.01$ ).

polyester and aluminium foil pouches for extruded. This decrease in fat content with increase in storage duration was non significant effect at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the fat content of the extrudates were non significant effect at  $p \leq 0.01$ . As the difference between the means of fat contents of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant effect at  $p \leq 0.01$  from each other.

The decrease in fat content in extruded snack may be attributed to the development of rancidity as a result of lipids hydrolysis that occurs during storage. The fat deterioration during storage may be attributed to activity of lipase enzyme which split off the fat into free fatty acids and glycerol in the presence of catalyst like moisture, light and heat. The main reason of decreasing fat content is oxidation of fat into fatty acids simultaneously with the time of storage (Saurabh *et al.* 2013). Fat content decreased with increase in storage durations. Similar findings were reported by Osundahunsi, 2006; Balfour *et al.* 2014; Saurabh *et al.* 2013, for extruded from soya bean with paintain flour blends, extruded fortified corn and snack food respectively. A decrease in fat content was also observed in all the packaging material with the increase in storage period from 0-60 days with non significant effect at  $p \leq 0.01$ .

### 3. Fiber content

Table 4 shows the effect of packaging material and storage duration on fiber content of extrudates. The fiber content decreased from 1.23 to 1.06 %, 1.23 to 1.03 % and 1.23 to 1.05 % in aluminium foil,

polyethylene and polyester respectively. Table 8 (c) shows the ANOVA for change in fiber content in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

Decrease in fiber content with increase in storage period from 0-60 days is higher in polyethylene pouches than polyester and aluminium foil pouches for extruded. This decrease in fiber content with increase in storage duration was non significant effect at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the fiber content of the extrudates was non significant effect at  $p \leq 0.01$ . As the difference between the means of fiber contents of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant difference at  $p \leq 0.01$  from each other.

Fiber content decreased with increase in storage durations. Similar findings were reported by Bhattacharya *et al.* 1994; Balfour *et al.* 2014 for extruded from rice and chick pea flour and extruded fortified corn respectively.

A decrease in fiber content was also observed in all the packaging material with the increase in storage period from 0-60 days with significant effect at  $p \leq 0.01$ .

### 4. Ash content

Table 5 shows the effect of packaging material and storage duration on ash content of extrudates. The ash content decreased from 1.99 to 1.83 %, 1.99 to 1.77 % and 1.99 to 1.81 % in aluminium foil, polyethylene and polyester respectively. Table 8 (d) shows the ANOVA for change in ash content in 60 days storage

**Table 4:** Effect of packaging material and storage duration on Fibre content of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	1.23 <sup>a</sup>	1.23 <sup>a</sup>	1.21 <sup>a</sup>	1.18 <sup>a</sup>	1.16 <sup>a</sup>	1.11 <sup>a</sup>	1.06 <sup>a</sup>
2	Polyethylene	1.23 <sup>a</sup>	1.21 <sup>a</sup>	1.17 <sup>a</sup>	1.14 <sup>a</sup>	1.11 <sup>ba</sup>	1.06 <sup>a</sup>	1.03 <sup>a</sup>
3	Polyester	1.23 <sup>a</sup>	1.21 <sup>a</sup>	1.19 <sup>a</sup>	1.16 <sup>a</sup>	1.13 <sup>b</sup>	1.10 <sup>a</sup>	1.05 <sup>a</sup>
SE		0.0000	0.0109	0.0118	0.0178	0.0095	0.0167	0.0279
CD at 1%		0.0000	0.0489	0.0529	0.0798	0.0428	0.0749	0.1251

Same letter are not significantly different ( $p \leq 0.01$ ).

**Table 5:** Effect of packaging material and storage duration on Ash content of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	1.99 <sup>a</sup>	1.98 <sup>a</sup>	1.96 <sup>a</sup>	1.93 <sup>a</sup>	1.91 <sup>a</sup>	1.87 <sup>a</sup>	1.83 <sup>a</sup>
2	Polyethylene	1.99 <sup>a</sup>	1.95 <sup>a</sup>	1.92 <sup>a</sup>	1.89 <sup>a</sup>	1.85 <sup>ba</sup>	1.81 <sup>a</sup>	1.77 <sup>a</sup>
3	Polyester	1.99 <sup>a</sup>	1.96 <sup>a</sup>	1.95 <sup>a</sup>	1.90 <sup>a</sup>	1.88 <sup>b</sup>	1.84 <sup>a</sup>	1.81 <sup>a</sup>
<b>SE</b>		0.0000	0.0089	0.0182	0.0128	0.0114	0.0149	0.0226
<b>CD at 1%</b>		0.0000	0.0399	0.0815	0.0573	0.0512	0.0667	0.1015

Same letter are not significantly different ( $p \leq 0.01$ ).

**Table 6:** Effect of packaging material and storage duration on Moisture content of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	6.65 <sup>a</sup>	6.69 <sup>a</sup>	6.68 <sup>a</sup>	6.69 <sup>a</sup>	6.73 <sup>b</sup>	6.80 <sup>a</sup>	6.83 <sup>a</sup>
2	Polyethylene	6.65 <sup>a</sup>	6.67 <sup>a</sup>	6.69 <sup>a</sup>	6.72 <sup>a</sup>	6.79 <sup>ba</sup>	6.82 <sup>a</sup>	6.84 <sup>a</sup>
3	Polyester	6.65 <sup>a</sup>	6.67 <sup>a</sup>	6.71 <sup>a</sup>	6.75 <sup>a</sup>	6.80 <sup>a</sup>	6.84 <sup>a</sup>	6.87 <sup>a</sup>
<b>SE</b>		0.0000	0.0098	0.0232	0.0415	0.0153	0.0234	0.0349
<b>CD at 1%</b>		0.0000	0.0442	0.1039	0.186	0.0684	0.105	0.1566

Same letter are not significantly different ( $p \leq 0.01$ ).

duration for arrowroot, lesser yam and potato based extrudates.

Decrease in ash content with increase in storage period from 0-60 days is higher in polyethylene pouches than polyester and aluminium foil pouches for extruded. This decrease in ash content with increase in storage duration was non significant at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the ash content of the extrudates was non significant at  $p \leq 0.01$ . As the difference between the means of ash contents of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant difference at  $p \leq 0.01$ .

Ash content decreased with increase in storage durations. Similar findings were reported by El-Samahy *et al.* 2006; Balfour *et al.* 2014 for extruded from rice and chick pea flour and extruded fortified corn respectively.

A decrease in ash content was also observed in all the packaging material with the increase in storage period from 0-60 days non significant at  $p \leq 0.01$ .

## 5. Moisture content

The effect of packaging material and storage period on the moisture content of extrudates.

Table 6 shows the effect of packaging material and storage duration on moisture content of extrudates. The moisture content increased from 6.65 to 6.83 %, 6.65 to 6.84 % and 6.65 to 6.87 % in aluminium foil, polyethylene and polyester respectively. Table 8 (e) shows the ANOVA for change in moisture content in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

Increase in moisture content with increase in storage period from 0-60 days is higher in polyester pouches followed by polyethylene and aluminium foil pouches for extruded. This increase in moisture content with increase in storage duration was non significant at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the moisture content of the extrudates were non significant at  $p \leq 0.01$ . As the difference between the means of moisture contents of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant difference at  $p \leq 0.01$  from each other.

Moisture content increased with increase in storage durations. Similar findings were reported by Akhtar *et al.* 2008; Elleuch *et al.* 2011; Balfour *et al.* 2014 for extruded from whole wheat flour, dietary fiber and fiber rich products and extruded fortified corn respectively.

A increase in moisture content was also observed in all the packaging material with the increase in storage period from 0-60 days non significant at  $p \leq 0.01$ .

## 6. Carbohydrates

Table 7 shows the effect of packaging material and storage duration on carbohydrate of extrudates. The carbohydrate increased from 85.80 to 86.01 %, 85.80 to 86.22 % and 85.75 to 86.73 % in aluminium foil, polyethylene and polyester respectively. Table 8 (f) shows the ANOVA for change in carbohydrate in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

**Table 7:** Effect of packaging material and storage duration on Carbohydrate of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	85.80 <sup>a</sup>	85.87 <sup>a</sup>	85.95 <sup>a</sup>	86.06 <sup>b</sup>	86.05 <sup>a</sup>	86.23 <sup>a</sup>	86.01 <sup>b</sup>
2	Polyethylene	85.80 <sup>a</sup>	85.92 <sup>a</sup>	86.00 <sup>a</sup>	86.12 <sup>ba</sup>	86.11 <sup>a</sup>	86.38 <sup>a</sup>	86.55 <sup>a</sup>
3	Polyester	85.75 <sup>a</sup>	85.98 <sup>a</sup>	86.10 <sup>a</sup>	86.28 <sup>a</sup>	86.42 <sup>a</sup>	86.57 <sup>a</sup>	86.73 <sup>a</sup>
SE		0.0207	0.0472	0.0970	0.0394	0.0861	0.0762	0.0712
CD at 1%		0.0927	0.2116	0.4348	0.1765	0.3861	0.3415	0.3191

Same letter are not significantly different ( $p \leq 0.01$ ).

**Table 8:** ANOVA for Nutritional properties of storage study

Source of Variation	SS	df	MS	F	P-value	F crit
<b>(a) Protein (%)</b>						
Between Groups	0.29236	6	0.04873	7.88341	0.00075	4.45582
Within Groups	0.08653	14	0.00618			
Total	0.3789	20				
<b>(b) Fat (%)</b>						
Between Groups	0.12579	6	0.02097	31.4476	2.4E-07	4.45582
Within Groups	0.00933	14	0.00067			
Total	0.13512	20				
<b>(c) Fiber (%)</b>						
Between Groups	0.08118	6	0.01353	37.8844	7.2E-08	4.45582
Within Groups	0.005	14	0.00036			
Total	0.08618	20				
<b>(d) Ash Content (%)</b>						
Between Groups	0.08183	6	0.01364	24.9043	1E-06	4.45582
Within Groups	0.00767	14	0.00055			
Total	0.0895	20				
<b>(e) Moisture content (%)</b>						
Between Groups	0.1014	6	0.0169	33.8431	1.5E-07	4.45582
Within Groups	0.00699	14	0.0005			
Total	0.10839	20				
<b>(f) Carbohydrates (%)</b>						
Between Groups	1.01945	6	0.16991	5.12381	0.00559	4.45582
Within Groups	0.46425	14	0.03316			
Total	1.4837	20				

Increase in carbohydrate with increase in storage period from 0-60 days is higher in polyethylene pouches followed by polyester and aluminium foil pouches for extruded. This increase in carbohydrate with increase in storage duration was no significant at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the carbohydrates content of the extrudates were non significant at  $p \leq 0.01$ . As the difference between the means of carbohydrate of extrudates at the entire interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant different at  $p \leq 0.01$ .

Carbohydrate increased with increase in storage durations. Similar findings were reported by Sumathi *et al.* 2007; Balfour *et al.* 2014 for extruded from pearl millet and extruded fortified corn respectively.

A increase in carbohydrate was also observed in all the packaging material with the increase in storage period from 0-60 days non significant effect at  $p \leq 0.01$ .

## Functional properties

### 1. Expansion ratio

The effect of packaging material and storage period on the expansion ratio of extruded prepared with

arrowroot (10%), lesser yam (40%) and potato (50%) is presented in Table 9.

Table 9 shows the effect of packaging material and storage duration on expansion ratio of extrudates. The expansion ratio increased from 3.06 to 3.10, 3.06 to 3.09 and 3.06 to 3.09 in aluminium foil, polyethylene and polyester respectively with 60 days of storage period. Table 14 (a) shows the ANOVA for change in expansion ratio in 20 days storage duration for arrowroot, lesser yam and potato based extrudates.

The expansion ratio with storage duration has non significant at  $p \leq 0.01$  for extrudates. Expansion ratio does not change with increase in storage durations the packaging material at  $p \leq 0.01$ .

### 2. Bulk density

The effect of packaging material and storage period on the bulk density of extruded prepared with arrowroot (10%), lesser yam (40%) and potato (50%) is presented in Table 10.

Table 10 shows the effect of packaging material and storage duration on bulk density of extrudates. The bulk density ranges from 0.18 to 0.09 g/cm<sup>3</sup>, 0.17 to 0.08 g/cm<sup>3</sup>, 0.18 to 0.10 g/cm<sup>3</sup> in aluminium foil, polyethylene and polyester respectively. Table 14 (b)

**Table 9:** Effect of packaging material and storage duration on Expansion ratio of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	3.06 <sup>a</sup>	3.09 <sup>a</sup>	3.10 <sup>a</sup>	3.06 <sup>a</sup>	3.08 <sup>a</sup>	3.08 <sup>a</sup>	3.09 <sup>a</sup>
2	Polyethylene	3.06 <sup>a</sup>	3.08 <sup>b</sup>	3.09 <sup>a</sup>	3.06 <sup>a</sup>	3.09 <sup>a</sup>	3.07 <sup>a</sup>	3.09 <sup>a</sup>
3	Polyester	3.06 <sup>a</sup>	3.06 <sup>ba</sup>	3.07 <sup>a</sup>	3.08 <sup>a</sup>	3.08 <sup>a</sup>	3.09 <sup>a</sup>	3.06 <sup>a</sup>
SE		0.0001	0.0087	0.0049	0.0068	0.0049	0.0042	0.0051
CD at 1%		0.0004	0.0388	0.0222	0.0304	0.0218	0.0189	0.0228

Same letter are not significantly different ( $p \leq 0.01$ ).

**Table 10:** Effect of packaging material and storage duration on Bulk density of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	0.18 <sup>a</sup>	0.16 <sup>a</sup>	0.16 <sup>a</sup>	0.14 <sup>a</sup>	0.13 <sup>a</sup>	0.11 <sup>ba</sup>	0.09 <sup>a</sup>
2	Polyethylene	0.17 <sup>a</sup>	0.15 <sup>ba</sup>	0.13 <sup>a</sup>	0.12 <sup>a</sup>	0.10 <sup>a</sup>	0.09 <sup>a</sup>	0.08 <sup>b</sup>
3	Polyester	0.18 <sup>a</sup>	0.15 <sup>b</sup>	0.15 <sup>a</sup>	0.13 <sup>a</sup>	0.12 <sup>b</sup>	0.11 <sup>b</sup>	0.10 <sup>a</sup>
SE		0.0004	0.0033	0.0055	0.0076	0.0019	0.0092	0.0073
CD at 1%		0.0017	0.0149	0.0247	0.0341	0.0086	0.0412	0.0327

Same letter are not significantly different ( $p \leq 0.01$ ).

shows the ANOVA for change in bulk density in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

Decrease in bulk density with increase in storage period from 0-60 days is higher in polyethylene pouches than polyester and aluminium foil pouches for extruded. This decrease in bulk density with increase in storage duration has non significant at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the bulk density of the extrudates were non significant at  $p \leq 0.01$ . As the difference between the means of bulk density of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant difference at  $p \leq 0.01$  from each other.

Bulk density increased with increase in storage durations. Similar findings were reported by Sumathi *et al.* 2007; Balfour *et al.* 2014 for extruded from pearl millet and extruded fortified corn respectively.

An increase in bulk density was also observed in all the packaging material with the increase in storage period from 0-60 days no significant at  $p \leq 0.01$ .

### 3. Water Absorption Index (WAI)

The effect of packaging material and storage period on the water absorption index of extruded proportions of arrowroot (10%), lesser yam (40%) and potato (50%) is presented in Table 11.

Table 11 shows the effect of packaging material and storage duration on water absorption index of extrudates. The water absorption index increased

from 4.27 to 4.54 g/g, 4.27 to 4.59 g/g and 4.27 to 4.57 g/g in aluminium foil, polyethylene and polyester respectively. Table 14 (c) shows the ANOVA for change in water absorption index in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

Increase in water absorption index with increase in storage period from 0-60 days is higher in polyethylene pouches than polyester and aluminium foil pouches for extruded. This increase in water absorption index with increase in storage duration was non significant at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the water absorption index of the extrudates were non significant at  $p \leq 0.01$ . As the difference between the means of water absorption index of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant difference at  $p \leq 0.01$ .

Water absorption index increased with increase in storage durations. Similar findings were reported by Rocha-Guzma'n *et al.* 2006 for common bean extrusion. Increase in water absorption index was also observed in all the packaging material with the increase in storage period from 0-60 days non significant at  $p \leq 0.01$ .

### 4. Water solubility index

The effect of packaging material and storage period on the water solubility index of extruded prepared with arrowroot (10%), lesser yam (40%) and potato (50%) is presented in Table 12.

**Table 11:** Effect of packaging material and storage duration on Water Absorption index of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	4.27 <sup>a</sup>	4.29 <sup>a</sup>	4.32 <sup>a</sup>	4.36 <sup>b</sup>	4.43 <sup>a</sup>	4.48 <sup>a</sup>	4.54 <sup>a</sup>
2	Polyethylene	4.27 <sup>a</sup>	4.33 <sup>a</sup>	4.37 <sup>a</sup>	4.44 <sup>ba</sup>	4.51 <sup>a</sup>	4.53 <sup>a</sup>	4.59 <sup>a</sup>
3	Polyester	4.27 <sup>a</sup>	4.31 <sup>a</sup>	4.34 <sup>a</sup>	4.39 <sup>a</sup>	4.46 <sup>a</sup>	4.52 <sup>a</sup>	4.57 <sup>a</sup>
<b>SE</b>		0.0000	0.0233	0.0376	0.0154	0.0201	0.0326	0.0221
<b>CD at 1%</b>		0.0000	0.1043	0.1686	0.069	0.0899	0.1461	0.0991

Same letter are not significantly different ( $p \leq 0.01$ ).

**Table 12:** Effect of packaging material and storage duration on Water Solubility index of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	31.34 <sup>a</sup>	32.00 <sup>a</sup>	33.00 <sup>a</sup>	35.67 <sup>a</sup>	37.67 <sup>a</sup>	39.67 <sup>a</sup>	42.67 <sup>a</sup>
2	Polyethylene	31.34 <sup>a</sup>	33.34 <sup>a</sup>	35.00 <sup>a</sup>	37.00 <sup>a</sup>	39.34 <sup>a</sup>	42.34 <sup>a</sup>	43.67 <sup>a</sup>
3	Polyester	31.34 <sup>a</sup>	32.67 <sup>a</sup>	34.00 <sup>a</sup>	36.67 <sup>a</sup>	38.34 <sup>a</sup>	41.67 <sup>a</sup>	43.00 <sup>a</sup>
<b>SE</b>		0.0000	0.5586	1.0220	1.0183	0.4389	0.6266	0.9149
<b>CD at 1%</b>		0.0000	2.5035	4.5805	4.5643	1.967	2.8083	4.1006

Same letter are not significantly different ( $p \leq 0.01$ ).

**Table 13:** Effect of packaging material and storage duration on Hardness of extrudates

Sl. No.	Packaging material	0	10	20	30	40	50	60
1	Aluminium foil	1412 <sup>a</sup>	1437 <sup>a</sup>	1466 <sup>a</sup>	1532 <sup>a</sup>	1548 <sup>a</sup>	1634 <sup>a</sup>	1658 <sup>a</sup>
2	Polyethylene	1412 <sup>a</sup>	1463 <sup>a</sup>	1542 <sup>a</sup>	1565 <sup>a</sup>	1649 <sup>a</sup>	1688 <sup>a</sup>	1723 <sup>a</sup>
3	Polyester	1412 <sup>a</sup>	1445 <sup>a</sup>	1490 <sup>a</sup>	1542 <sup>a</sup>	1567 <sup>a</sup>	1651 <sup>a</sup>	1694 <sup>a</sup>
<b>SE</b>		0.00	101.20	68.07	36.75	57.25	39.64	90.88
<b>CD at 1%</b>		0.00	453.57	305.09	164.73	256.61	177.69	407.33

Same letter are not significantly different ( $p \leq 0.01$ ).

Table 12 shows the effect of packaging material and storage duration on water solubility index of extrudates. The water solubility index increased from 31.34 to 42.67 %, 31.34 to 43.67 % and 31.34 to 43.00 % in aluminium foil, polyethylene and polyester respectively. Table 14 (d) shows the ANOVA for change in water solubility index in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

Increase in water solubility index with increase in storage period from 0-60 days is higher in polyethylene pouches than polyester and aluminium foil pouches for extruded. This increase in water solubility index with increase in storage duration was no significant at  $p \leq 0.01$  for extrudates. The effect of packaging materials and storage durations on the water solubility index of the extrudates were non significant at  $p \leq 0.01$ . As the difference between the means of water solubility index of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant difference at  $p \leq 0.01$ .

Water solubility index increased with increase in

storage durations. Similar findings were reported by Rocha-Guzma'n *et al.* 2006 for common bean extrusion. A increase in water solubility index was also observed in all the packaging material with the increase in storage period from 0-60 days (non significant difference at  $p \leq 0.01$ ).

### 5. Hardness

The effect of packaging material and storage period on the hardness of extruded prepared with proportions of arrowroot (10%), lesser yam (40%) and potato (50%) is presented in Table 13.

Table 13 shows the effect of packaging material and storage duration on hardness of extrudates. The hardness increased from 1412 to 1658 g, 1412 to 1723 g and 1412 to 1694 g in aluminium foil, polyethylene and polyester respectively. Table 14 (e) shows the ANOVA for change in hardness in 60 days storage duration for arrowroot, lesser yam and potato based extrudates.

Increase in hardness with increase in storage period from 0-60 days is higher in polyethylene pouches

**Table 14:** ANOVA for Functional properties of storage study

Source of Variation	SS	df	MS	F	P-value	F crit
<b>(a) Expansion ratio</b>						
Between Groups	0.00163	6	0.00027	1.83871	0.163	4.45582
Within Groups	0.00207	14	0.00015			
Total	0.0037	20				
<b>(b) Bulk density (g/cm<sup>3</sup>)</b>						
Between Groups	0.01645	6	0.00274	22.141	2.2E-06	4.45582
Within Groups	0.00173	14	0.00012			
Total	0.01818	20				
<b>(c) Water Absorption Index (g/g)</b>						
Between Groups	0.21591	6	0.03599	44.716	2.4E-08	4.45582
Within Groups	0.01127	14	0.0008			
Total	0.22718	20				
<b>(d) Water Solubility Index (%)</b>						
Between Groups	350.975	6	58.4958	84.8802	3.4E-10	4.45582
Within Groups	9.6482	14	0.68916			
Total	360.623	20				
<b>(e) Hardness (g)</b>						
Between Groups	195426	6	32571	34.211	1.4E-07	4.45582
Within Groups	13328.9	14	952.062			
Total	208755	20				

than polyester and aluminium foil pouches for extrudates. This increase in hardness with increase in storage duration for extrudates was non significant at  $p \leq 0.01$ . The effect of packaging materials and storage durations on the hardness of the extrudates were non significant at  $p \leq 0.01$ . As the difference between the means of hardness of extrudates at all the interval for polyethylene, polyester and aluminium foil pouches was higher than CD and has non significant difference at  $p \leq 0.01$  from each other.

Hardness increased with increase in storage durations. A increase in hardness was also observed in all the packaging material with the increase in storage period from 0-60 days (non significant at  $p \leq 0.01$ ).

## CONCLUSION

Following conclusions can be made from the present study:

1. Effect of packaging material (Aluminium

foil, polyethylene and polyester) and storage durations (0,10, 20, 30, 40, 50 and 60 days) on the nutritional properties of extrudates (Arrowroot: Lesser yam: Potato i.e. 10:40:50) indicated that the non significant changes  $p \leq 0.01$  has been observed in protein, fat, fiber, ash, moisture and carbohydrates of these extrudates.

2. Effect of packaging material (Aluminium foil, polyethylene and polyester) and storage durations (0,10, 20, 30, 40, 50 and 60 days) on the functional properties of extrudates (Arrowroot: Lesser yam: Potato i.e. 10:40:50) indicated that the non significant changes  $p \leq 0.01$  has been observed in expansion ratio, bulk density, water absorption index, water solubility index and hardness of these extrudates.

3. Aluminium foil is the best packaging material to store the extrudates up to 60 days. The nutritional properties at the 60 days period were protein 2.70 %, fat 1.22 %, fiber 1.06 %, ash 1.83 %, moisture 50.12 %, and carbohydrates 43.28 %.

carbohydrates 86.01 % and moisture 6.83 %. The functional properties of the extrudates at 60 days period in the aluminium foil is expansion ratio 3.09, bulk density 0.09 g/cm<sup>3</sup>, water absorption index 4.54 g/g, water solubility index 42.67 %, and hardness of extrudates 1658 g respectively.

4. Extrudates can be stored in good condition in aluminium foil up to 2 months with better retention of nutritional and functional properties.

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