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# Evaluation of Sticky Rice Flour, Jack Fruit Seed Flour and Tapioca Flour as Fillers in Pork Nuggets

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## ABSTRACT

Sticky rice flour, jackfruit seed flour and tapioca flour were evaluated as alternate fillers to completely replace the wheat flour in the formulation for processing pork nuggets. Incorporation of sticky rice flour and jackfruit seed flour at 3.5% level in the formulation had no significant effect on any of the important physico-chemical, microbiological and sensory parameters of the nuggets. Products containing sticky rice flour did show even some of the better quality parameters compared to that containing wheat flour. Also, complete replacement of wheat flour with tapioca flour in the formulation resulted in significant reduction in most of the physico-chemical and sensorial properties of nuggets. The results indicated that pork nuggets with 'very good' consumer acceptability could be processed by completely replacing wheat flour with sticky rice flour and jackfruit seed flour as fillers and the products thus processed had a storage life of 21 days at 4±1$^{o}$C.

**Keywords:** *Sticky rice flour, Jackfruit seed flour, Tapioca flour, Filler, Pork nuggets*

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## INTRODUCTION

Sticky rice *(Oryza sativa var. glutinosa)*, called bora saul in local language, is cultivated extensively in the north eastern region of India, especially in the state of Assam. Commonly known as glutinous or waxy rice, sticky rice is a type of short or long-grained rice that is especially sticky when cooked. Sticky rice is known for its bland taste, attractive white colour and ease of digestion (Kadan et al. 2003). Sticky rice differs from other types of rice in that the grain starch contains essentially no amylose (0–2% dry basis) and high amount of amylopectin, which is responsible for the sticky quality of cooked sticky rice (Wittenberg 2007; Kang et al. 2010). Jackfruit (Artocarpus heterophyllus) is native to India and grows wild in the rain forests of Western Ghats of India (Reddy et al. 2004). Largest of all tree-borne fruits, there may be 100 or up to 300 seeds in a single fruit. Seeds make up around 10 to 15 % of the total fruit mass and have high carbohydrate and protein contents (Kumar et al. 1988). As fresh seeds cannot keep for long time, seed flour can be an alternative product, which could be used effectively in some food products (Abedin et al. 2012). Tapioca is an energy-dense food and ranked high for its calorific value and the tubers are the physiological energy reserve with high carbohydrate content, which ranges from 32% to 35% on a fresh weight basis, and from 80% to 90% on a dry matter basis (Emmanuel et al., 2012). The tubers contain significant amounts of vitamins, particularly vitamin C, thiamine, riboflavin, niacin, calcium and phosphorous (Audu et al. 2012). It is reported that tapioca starch can perform most of the functions where maize, rice and wheat starch are currently used (Tonukari 2004; Montagnac et al. 2009).

Fillers in meat processing are non-meat substances, high in carbohydrates and are primarily used with the objective of making meat products at a lower-cost. In addition, they are added to improve the textural properties of processed meat products (Lawrie 1998). Also, fillers could improve the water holding capacity and thereby reduce the cooking loss in the processed meat products. The safe limit has been usually set at 3.5-5.0% of the total formulation (Anjaneyulu et al. 1995; USDA, 2012). In India, wheat flour is the most preferred filler for processing meat products. Currently there has been little research done in muscle foods using sticky rice powder, jackfruit seed powder and tapioca flour, as fillers. Therefore, in this study, these underutilized and abundantly available plant resources were used as fillers and were compared with wheat flour to evaluate their effectiveness in processing pork nuggets.

## MATERIALS AND METHODS

Collection and processing of sticky rice, jackfruit seed and tapioca tuber: Sticky rice, ripe jackfruit seeds and tapioca tubers were collected (3.0 kg each) from the local market of Kamrup District, Assam. In case of sticky rice, the flour was prepared by wet grinding in the institute's processing unit. Rice was steeped in water at the ratio of water: rice of 2:1 (w/w) for 2 hr, drained well and then spread on a clean cloth and air dried for another 30 min. When the rice was still damp to touch, it was powdered in a domestic mixer at medium speed for 3 min and passed through 35 mesh sieve (0.5 mm diameter). The left over coarse particles were again ground in the same mixer for another 2.0 min and sieved again. The flour was then dried to constant moisture in a hot air oven (NSW make, New Delhi) at 60$^{o}$C for 8 hr. The dried rice flour was then spread on a clean cloth and allowed to cool down for 20 min and then packaged into polyethylene bags and kept at room temperature (25-28$^{o}$C) for further use.

The jackfruit seeds were cleaned manually and white arils (seed coat) were manually peeled off. Seeds were lye peeled, soaking in 3 per cent sodium hydroxide solution for 3-5 min to remove the thin brown spermoderm which covers the cotyledons. The spermoderm layer was removed by rubbing the seeds between the hands and washing thoroughly under running water. The lye peeled seeds were sliced into thin chips and dried for 48hr at 60°C in a hot air oven. Similarly, in case of tapioca, the tubers were cleaned, peeled and washed with potable water. The tubers were then cut into cubes of 1.0-1.5cm3 sizes and oven dried at 60$^{o}$C for 48 hr. In both cases, the oven dried samples were powdered in a domestic mixer at medium speed for 3 min and passed through 35 mesh sieve (0.5

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mm diameter). The left over coarse particles were again ground in the same mixer for another 2.0 min and sieved again. The flour obtained was spread on a clean cloth and allowed to air dry for 30 min and then packaged into polyethylene bags and kept at room temperature (25-28°C) for further use. Further, commercially available brand of wheat flour (Annapurna brand, ITC, Kolkata) was procured from the local market and was used for processing control nuggets.

***Lean pork, pork fat and processing ingredients:*** Lean pork and fat (back fat) required for the experiments were obtained from the crossbred pigs (50% Ghungroo x 50% Hampshire) of 8-9 months age, slaughtered as per standard procedures at the R&D pig slaughter house and pork processing plant (HACCP and ISO 9001:2008 certified- certificate number – 1100263) of National Research Centre on Pig, Rani, Guwahati. Meat and fat were obtained from ham portion of the carcass within 0.5 hr of slaughter and deboning was done at the processing plant after conditioning in a refrigerator at 4±1°C for about 16 hr. Additional back fat was obtained from loin portion, if required. Meat was cut into cubes of about 3 cm and ground using a 13 mm plate followed by an 8 mm one, in a Sirman meat grinder. Fat was ground using a13 mm plate followed by 3 mm plates in the same grinder. The meat and fat were packaged in LDPE bags and kept frozen (-18±1°C) till subsequent use and were thawed at 4±1°C for 6-8 hr before use. Condiments required for processing were procured from the local market. Fine paste of onion and garlic in the ratio 3:1 was used as condiments mix. Various ingredients required to prepare the spices were procured from the local market and dried in a hot air oven at 50°C for 4 hr followed by grinding and mixing in the laboratory at required proportions to suit the local taste. Chemicals that are to be incorporated in the formulation were procured of food grade quality, from reputed firms. Chemicals, reagents (AR grade) and readymade media for microbiological studies and quality evaluation were procured from standard companies for various laboratory analyses.

***Processing of pork nuggets:*** Meat emulsions were prepared using a Mado food cutter (Model MTK 661, Serial No.113165, Postfach, Schwarzwald, Germany) with 10% pork fat. Two kilogram batches were made with the following ingredients, namely, 1400 g lean, 200 g fat, 200 g ice flakes, 34 g salt, 6 g sodium tri polyphosphate, 60 g condiments mix, 30 g spice mix, 70 g wheat flour (3.5%) and 0.3 g sodium nitrite (0.015%). This formulation was served as the control batch. The temperature of the final emulsion was around 10-12oC. In case of treatment groups, the base formulation remained same as that mentioned above (2.0 kilogram batches), except that the wheat flour was replaced by sticky rice flour, jackfruit seed flour and tapioca flour in their respective formulations, at the same level (3.5%).

Meat emulsion (600 g) was placed in stainless steel moulds (17 x 11 x 4.5 cm), packed compactly and covered. The moulds were then clipped and tied and the meat blocks were cooked in a steam oven without pressure for 40 min. The internal temperature of cooked blocks was 85°C as measured using a probe type thermometer (Oakton, China). The meat blocks were cooled to room temperature and cut into slices of 15 mm thickness, using a meat slicer (Sirman, model Gemma 300 CE, Pieve di Curtarolo, Italy). The slices were manually cut into nuggets (15 mm). The nuggets were aerobically packed in cast polypropylene bags, in such a way that each bag contains about 300 g nuggets, using a Sevena packaging machine. One packet from each group was used for evaluation of physico-chemical, microbiological and sensory attributes of the product on the day of processing. The remaining packets from each group were kept at 4±1°C and examined at intervals of seven days up to 28 days.

***Analytical procedures:*** pH was determined using a digital pH meter (Elico, Model LI 127, India). The procedure of Kondaiah et al. (1985) was followed to measure cooking yield and emulsion stability. The moisture, crude protein, fat, ash and crude fibre contents were determined by Association of Official Analytical Chemists' approved methods 925.10, 920.87, 920.85, 923.03 and 963.09 respectively (AOAC 2005). Carbohydrate content was determined by difference. The procedure of Tarladgis et al. (1960) was followed to estimate the TBARS (thiobarbituric acid reacting substances) number as mg of malonaldehyde per kg of sample. The procedure of Strange et al. (1977) was followed to determine the tyrosine value. The method described by Koniecko (1979) was followed for measuring titratable acidity. The water and oil absorption capacities of different flours were determined by the method of Sosulski et al. (1976). The colour of all the samples was measured by using a Hunter colour lab (Model Colour Flex; Hunter Associates Laboratory, VA, USA) with an 8 mm aperture set for illumination D45/10o standard observer angle. Texture profile analysis was conducted as per the procedure described by Bourne (1978) using a Stable Microsystems Texturometer (Stable Microsystems Ltd. Surrey, UK) model TA-XT2 texture analyzer attached to a software, texture expert. Amino acid profile was analyzed by Near Infrared (NIR) method (Perten Instruments, Sweden).

Microbiological parameters of pork nuggets were determined as per the methods described by ICMSF (1996). Readymade media from Hi-Media Laboratories (P) Ltd, Mumbai, were used for enumeration of different microbes. Duplicate plates were prepared and the counts were expressed as colony forming units (cfu) per gram. Standard sensory evaluation method using 8-point descriptive scale (Keeton, 1983) was followed with modifications, where 8=excellent; 1=extremely poor. The experiments were replicated a minimum of three times and the data generated for different quality characteristics were compiled and analyzed using SPSS software (Version 13.0).

## RESULTS AND DISCUSSION

Proximate composition, water and oil absorption capacities of different flours: The proximate composition of four flours used in this experiment viz. wheat flour (control), sticky rice flour, jackfruit seed flour and tapioca flour are shown in Fig. 1. The major component of all the flours was carbohydrates which ranged from 70.39% (wheat flour) to 83.68% (tapioca flour). Moisture content varied from 9.61% in sticky rice flour to 14.07% in jackfruit seed flour. Proximate analysis showed that both sticky rice flour and jackfruit seed flour contain good amount of crude protein and crude fat, which were even comparable with that of wheat flour.

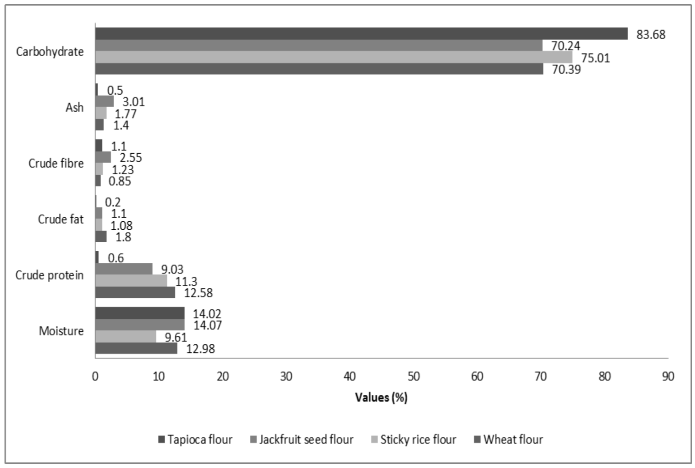


**Fig. 1: Proximate composition of the flours used in the experiment**

However, tapioca flour contained significantly ($P<0.01$) lower (almost nil) protein (0.60%) and fat (0.20%) compared to other flours. Jackfruit seed flour had 3 and 2 times higher crude fibre content than that of wheat flour and sticky rice flour, respectively. Similarly, jackfruit seed flour had almost 2 times higher ash content compared to wheat flour and sticky rice flour, while it was almost 6 times higher when compared with tapioca flour. The results indicated that sticky rice and jackfruit seed flours contained significant amounts of protein and were even comparable to that of wheat flour, while crude protein in the tapioca flour was almost zero. Many researchers have earlier analyzed and reported the proximate composition of these flours and the present results are comparable with their findings and those requires special mention are Kang et al. (2010) (sticky rice flour); Abedin et al. (2012) (jackfruit seed flour); Audu et al. (2012) (tapioca flour) and Islam et al. (2012) (wheat flour). The slight differences observed in the present study could be attributed to the variety differences, stage of maturation and environmental conditions. Water and oil absorption capacities of the flours are reported in Fig. 2. Water absorption capacity was highest in wheat flour (145.97%) while it was lowest in jackfruit seed flour (112.10%). Oil absorption capacity was highest in sticky rice flour (196.25%) and lowest in tapioca flour (80.01%). Wheat flour and jackfruit seed flour had an oil absorption capacity of 161.19% and 126.90%, respectively.

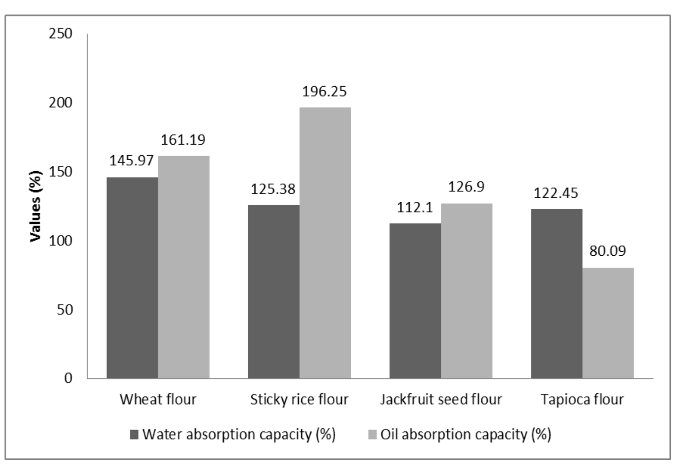


**Fig. 2: Water and oil absorption capacities of flours used in the experiment**

**Physico-chemical characteristics of pork nuggets containing different flours:** Incorporation of sticky rice flour, jackfruit seed flour or tapioca flour in place of wheat flour (control) in the formulation had no significant ($P>0.05$) effect either on the pH of raw emulsion or cooked nuggets (Table 1). The slight increase in the pH observed in cooked nuggets, over the corresponding raw emulsions, could be attributed to the higher degree of protein denaturation and the release of free –SH groups on cooking (Lawrie 1998). Addition of tapioca flour in the formulation has resulted in significant ($P<0.05$) reduction in the emulsion stability and cooking yield. This could possibly due to the reduction in water and fat binding properties resulted from the significantly ($P<0.01$) lower protein content observed in the tapioca flour (Fig. 1).

**Table 1: Effects of addition of sticky rice powder, jackfruit seed powder and tapioca flour on the physico-chemical parameters of pork nuggets.**

| Parameter | Control | Treatment | | |
|---|---|---|---|---|
| | | SRF | JSF | TPF |
| **Physico-chemical parameters** | | | | |
| Emulsion pH | 5.98±0.05 | 5.97±0.05 | 5.98±0.05 | 5.96±0.05 |
| Product pH | 6.04±0.08 | 6.07±0.08 | 6.04±0.08 | 6.09±0.08 |
| Emulsion stability (%) | 97.14±0.11$^{a}$ | 97.53±0.1$^{a}$ | 96.12±0.11$^{b}$ | 93.17±0.11$^{c}$ |
| Cooking yield (%)# | 97.25±0.73$^{a}$ | 97.13±0.73$^{a}$ | 96.94±0.73$^{a}$ | 93.52±0.53$^{b}$ |
| Moisture (%) | 67.33±0.15$^{b}$ | 68.57±0.1 $^{a}$ | 67.13±0.15$^{b}$ | 66.41±0.15$^{c}$ |
| Protein (%) | 15.90±0.12$^{b}$ | 15.63±0.12$^{b}$ | 15.61±0.12$^{b}$ | 17.61±0.12$^{a}$ |
| Fat (%) | 11.03±0.10$^{a}$ | 10.89±0.10$^{a}$ | 11.43±0.10$^{a}$ | 10.12±0.10$^{b}$ |
| Fibre (%) | 0.53±0.12$^{b}$ | 0.69±0.12$^{b}$ | 0.93±0.12$^{a}$ | 0.35±0.12$^{c}$ |
| NFE (%) | 2.49±0.16$^{b}$ | 2.45±0.19$^{b}$ | 2.46±0.16$^{b}$ | 2.95±0.10$^{a}$ |
| Ash (%) | 2.72±0.13$^{a}$ | 1.77±0.13$^{b}$ | 2.44±0.13$^{a}$ | 2.56±0.13$^{a}$ |
| **Instrumental colour scores** | | | | |
| | 60.62±0.06$^{c}$ | 65.94±0.09$^{a}$ | 61.27±0.07$^{b}$ | 60.86±0.02$^{c}$ |
| | 11.15±0.02$^{a}$ | 9.94±0.06$^{b}$ | 10.00±0.02$^{b}$ | 7.95±0.03$^{c}$ |
| | 16.79±0.03$^{a}$ | 16.85±0.07$^{a}$ | 16.78±0.09$^{a}$ | 13.64±0.09$^{b}$ |
| Chroma | 20.16±0.09$^{a}$ | 19.56±0.02$^{a}$ | 19.53±0.06$^{a}$ | 15.79±0.07$^{b}$ |
| | 56.41±0.07$^{b}$ | 59.46±0.03$^{a}$ | 59.19±0.03$^{a}$ | 59.77±0.06$^{a}$ |
| **Texture profiles** | | | | |
| Hardness (N/cm2) | 17.83±0.06$^{a}$ | 17.95±0.07$^{a}$ | 16.76±0.09$^{b}$ | 14.13±0.07$^{c}$ |
| Adhesiveness (Ns) | -0.035±0.06$^{c}$ | -0.076±0.07$^{b}$ | -0.045±0.01$^{c}$ | -0.085±0.07$^{a}$ |
| Springiness (cm) | 0.885±0.02$^{a}$ | 0.893±0.02$^{a}$ | 0.886±0.00$^{a}$ | 0.804±0.02b |
| Cohesiveness (Ratio) | 0.322±0.06 | 0.355±0.09 | 0.328±0.09 | 0.343±0.09 |
| Gumminess (N/cm2) | 57.40±0.09$^{a}$ | 56.72±0.05$^{a}$ | 57.60±0.05$^{a}$ | 52.11±0.05$^{b}$ |
| Chewiness (N/cm) | 50.70±0.09$^{a}$ | 50.63±0.09$^{a}$ | 49.60±0.01$^{a}$ | 47.53±0.09$^{b}$ |
| Fracturability (N) | 0.112±0.05$^{c}$ | 0.122±0.02$^{b}$ | 0.134±0.07$^{a}$ | 0.109±0.02$^{c}$ |
| Shear force (N) | 36.61±0.07$^{b}$ | 38.90±0.06$^{a}$ | 34.08±0.08$^{c}$ | 30.63±0.06$^{d}$ |
| Work of shearing (Ns) | 224.78±0.02$^{b}$ | 238.85±0.07$^{a}$ | 209.25±0.09$^{c}$ | 188.07±0.07$^{d}$ |

n=9; #n=3
SRF- Sticky rice flour; JSF- Jackfruit seed flour; TPF- Tapioca flour
Means with different superscripts in the same row indicate significant difference (P<0.05)

Results also indicated that the formulation with sticky rice flour had comparable (even better) emulsion stability (97.53%) and cooking yield (97.57%) with that of wheat flour (97.14% & 97.25% respectively). However, it was also evident from the results that even in the formulation with tapioca flour, both the emulsion stability and the cooking yield were well above the range required for profitable meat product processing i.e. more than 90% yield after cooking (Anjaneyulu et al. 1995). Proximate analysis of the cooked nuggets indicated a significant (P<0.05) decrease in the moisture and fat percentage in the products with tapioca flour (Table 1) and the significant increase in protein, ash and NFE contents observed in them might be proportional and could be attributed to the higher moisture and fat loss occurred during cooking, as indicated by significantly lower cooking yield. Results also indicated that the products with sticky rice flour and jackfruit seed flour had moisture, protein, fat and NFE components comparable to that of nuggets containing wheat flour. The significantly (P<0.05) higher fibre content observed in the nuggets with jackfruit seed flour could be attributed to the presence of comparatively higher crude fibre content in the raw jackfruit seed flour, as shown in Fig.1.

Lightness (L*) of the nuggets improved significantly with the addition of sticky rice flour, while the redness (a*) and yellowness (b*) were comparable in the products with wheat flour, jackfruit seed flour and sticky rice flour (Table 1). It is repo``rted that sticky rice becomes more translucent, when cooked (Wiset et al. 2011) and this phenomenon could be attributed to the increased lightness observed in nuggets with sticky rice flour. Addition of tapioca flour has resulted in significant reduction of both a* and b* parameters in nuggets. Hue angle, which measures the saturation of light, was improved significantly in all the treatment groups, while chroma has shown a significant reduction and the effect was more pronounced in the nuggets with tapioca flour. Texture profile analysis indicated that incorporation of tapioca flour in place of wheat flour in the product formulation has resulted in significant (P<0.05) reduction in almost all the textural parameters of the pork nuggets. Also, the products with sticky rice flour had even better hardness, springiness and fracturability compared to the nuggets containing wheat flour. The significantly (P<0.05) lower springiness values observed in nuggets with tapioca flour might be due to the reduction in elasticity of the products as a result of increased moisture and fat loss (Lawrie 1998) that occurred in them as indicated by significantly lower emulsion stability and cooking yield. Estimation of amino acid profiles indicated that there exist no significant (P>0.05) difference among the treatment groups (Table 2).

**Table 2: Amino acid composition (g/100g) of pork nuggets.**

| Parameter | Control Mean ±SEM | SRF Mean ±SEM | JRF Mean ±SEM | TPF Mean ±SEM |
|---|---|---|---|---|
| Aspartic acid | 1.12±0.18 | 1.10±0.11 | 1.03±0.07 | 1.17±0.10 |
| Serine | 0.58±0.11 | 0.59±0.11 | 0.55±0.09 | 0.61±0.06 |
| Glutamic acid | 2.27±0.27 | 2.25±0.28 | 2.12±0.16 | 2.31±0.23 |
| Glysine | 0.01±0.01 | 0.01±0.01 | 0.01±0.01 | 0.01±0.01 |
| Histidine | 1.57±0.22 | 1.44±0.17 | 1.56±0.20 | 1.62±0.15 |
| Arginine | 1.47±0.13 | 1.55±0.16 | 1.47±0.11 | 1.40±0.10 |
| Threonine | 0.59±0.08 | 0.57±0.03 | 0.51±0.06 | 0.63±0.05 |
| Alanine | 0.41±0.07 | 0.42±0.05 | 0.39±0.04 | 0.44±0.03 |
| Proline | 0.92±0.11 | 0.82±0.08 | 0.90±0.10 | 1.02±0.07 |
| Cystine | 0.16±0.01 | 0.18±0.01 | 0.15±0.02 | 0.19±0.01 |
| Tyrosine | 0.40±0.03 | 0.47±0.02 | 0.43±0.06 | 0.51±0.04 |
| Valine | 0.45±0.03 | 0.55±0.03 | 0.50±0.07 | 0.42±0.05 |
| Methionine | 0.30±0.01 | 0.24±0.01 | 0.22±0.02 | 0.26±0.01 |
| Lysine | 0.87±0.04 | 0.92±0.04 | 0.84±0.06 | 0.95±0.03 |
| Isoleucine | 0.36±0.01 | 0.43±0.01 | 0.39±0.03 | 0.42±0.05 |
| Leucine | 0.81±0.07 | 0.85±0.03 | 0.78±0.09 | 0.83±0.10 |
| Phenylalanine | 0.52±0.03 | 0.45±0.05 | 0.42±0.04 | 0.47±0.06 |
| Tryptophan | 0.27±0.03 | 0.26±0.01 | 0.29±0.08 | 0.23±0.05 |

n=9

SRF- Sticky rice flour; JSF- Jackfruit seed flour; TPF- Tapioca flour

Means with different superscripts (letters in the same row and numbers in the same column) indicate significant difference (P<0.05)

Quality changes in pork nuggets with different flours during refrigeration storage: Nuggets from all the groups, packaged in polyethylene bags and kept at refrigeration temperature (4±1oC), were drawn and evaluated at 7 days interval to assess the changes in different physico-chemical, microbiological and sensory parameters. The nuggets were not subjected to sensory evaluation on the day they were spoiled, but physico-chemical and microbiological parameters were determined. The acceptable/ unacceptable distinction was made mostly on the basis of flavour changes detected at the time of opening of the packets. The colour changes and sliminess developed were also considered.

Physico-chemical characteristics: As mentioned above, pH of nuggets from control and treatment groups did not differ significantly ($P>0.05$), on the day of processing (Table 3). However, the pH of nuggets from all the groups increased significantly ($P<0.05$) from 14 to 28 day of storage and the rate of increase was more prominent in the nuggets containing tapioca flour. Also, pH reached above 6.45 in nuggets from all the groups on 28th day of storage and the sensory analysis on that day revealed that the products were spoiled (Table 5). This could be attributed to the significant ($P<0.05$) increase in microbial load observed in all the products on day 28 of storage (Table 4), as it has been reported that increases in spoilage organisms results in more protein degradation in meat products, which in turn increases their pH, attributed to the accumulation of more metabolites (Lawrie 1998). TBARS values, which indicates the oxidative stability of products, did not differ significantly ($P>0.05$) among treatments on the day of processing (Table 3), while it showed an increasing trend during subsequent storage period in all the groups. This could be attributed to the increased rate of lipid oxidation with increasing levels of microbial population (Table 4) with the elapse of storage time, as a positive correlation between microbial load and TBARS number was reported in ground buffalo meat preblended with sodium ascorbate (Anjaneyulu et al. 1995).

**Table 3: Effect of addition of sticky rice powder, jackfruit seed powder and tapioca flour on the physico-chemical parameters of pork nuggets during refrigeration storage.**

| **Treatment/ Parameter** | **Storage period (days)** | | | | |
|---|---|---|---|---|---|
| | **0** | **7** | **14** | **21** | **28** |
| Control | $6.04\pm0.02^{d}$ | $6.07\pm0.03^{d2}$ | $6.13\pm0.01^{c2}$ | $6.21\pm0.03^{b2}$ | $6.46\pm0.02^{a2}$ |
| | $6.07\pm0.02^{c}$ | $6.08\pm0.03^{c2}$ | $6.11\pm0.02^{c2}$ | $6.19\pm0.04^{b2}$ | $6.45\pm0.02^{a2}$ |
| | $6.04\pm0.02^{d}$ | $6.10\pm0.03^{c2}$ | $6.15\pm0.02^{b2}$ | $6.18\pm0.04^{b2}$ | $6.45\pm0.02^{a2}$ |
| | $6.09\pm0.02^{e}$ | $6.17\pm0.03^{d1}$ | $6.23\pm0.02^{c1}$ | $6.29\pm0.04^{b1}$ | $6.53\pm0.02^{a1}$ |
| **TBARS value (mg malonaldehyde/kg)** | | | | | |
| Control | $0.67\pm0.02^{e}$ | $0.94\pm0.02^{d2}$ | $1.14\pm0.04^{c2}$ | $1.38\pm0.01^{b3}$ | $1.58\pm0.07^{a2}$ |
| SRF | $0.69\pm0.04^{e}$ | $0.99\pm0.05^{d2}$ | $1.12\pm0.02^{c2}$ | $1.42\pm0.02^{b3}$ | $1.60\pm0.04^{a2}$ |
| JSF | $0.73\pm0.04^{e}$ | $1.03\pm0.05^{d2}$ | $1.18\pm0.02^{c2}$ | $1.46\pm0.02^{b2}$ | $1.63\pm0.04^{a2}$ |
| TPF | $0.71\pm0.04^{e}$ | $1.19\pm0.05^{d1}$ | $1.31\pm0.02^{c1}$ | $1.54\pm0.02^{b1}$ | $1.93\pm0.04^{a1}$ |
| **Tyrosine value (mg/g)** | | | | | |
| Control | $0.70\pm0.02^{e}$ | $1.13\pm0.02^{d2}$ | $1.50\pm0.03^{c2}$ | $1.81\pm0.04^{b3}$ | $2.75\pm0.03^{a3}$ |
| SRF | $0.68\pm0.03^{e}$ | $1.14\pm0.02^{d2}$ | $1.45\pm0.03^{c2}$ | $1.73\pm0.03^{b4}$ | $2.45\pm0.04^{a4}$ |
| JSF | $0.73\pm0.02^{e}$ | $1.15\pm0.02^{d2}$ | $1.56\pm0.02^{c2}$ | $1.92\pm0.02^{b2}$ | $2.96\pm0.03^{a2}$ |
| TPF | $0.78\pm0.03^{e}$ | $1.20\pm0.02^{d1}$ | $1.68\pm0.03^{c1}$ | $2.10\pm0.03^{b1}$ | $3.25\pm0.04^{a1}$ |
| **Titratable acidity (ml 0.01N NaOH/g)** | | | | | |
| Control | $0.30\pm0.02^{c}$ | $0.25\pm0.03^{c1}$ | $0.28\pm0.03^{b1}$ | $0.21\pm0.03^{a1}$ | $0.16\pm0.04^{a1}$ |
| SRF | $0.30\pm0.02^{c}$ | $0.25\pm0.02^{bc1}$ | $0.29\pm0.04^{b1}$ | $0.21\pm0.04^{a1}$ | $0.16\pm0.02^{a1}$ |
| JSF | $0.30\pm0.02^{d}$ | $0.24\pm0.04^{d1}$ | $0.27\pm0.02^{c1}$ | $0.19\pm0.04^{b1}$ | $0.14\pm0.04^{a1}$ |
| TPF | $0.29\pm0.02^{d}$ | $0.15\pm0.02^{c2}$ | $0.19\pm0.04^{b2}$ | $0.15\pm0.04^{a2}$ | $0.10\pm0.02^{a2}$ |

n=9, SRF- Sticky rice flour; JSF- Jackfruit seed flour; TPF- Tapioca flour

Means with different superscripts (letters in the same row and numbers in the same column) indicate significant difference ($P<0.05$)

Also, the increase in TBARS values was significantly ($P<0.05$) higher in nuggets containing tapioca flour and this could be due to the inclusion of more air inside the product lattice resulted from its weak binding properties, as indicated by textural analysis (Table 1).

**Table 4: Effect of addition of sticky rice powder, jackfruit seed powder and tapioca flour on the microbiological parameters of pork nuggets during refrigeration storage.**

| Treatment/ Parameter | Storage period (days) 0 | 7 | 14 | 21 | 28 |
|---|---|---|---|---|---|
| **Total viable count (log cfu/g)** | | | | | |
| Control | 4.47±0.10$^{d}$ | 4.62±0.14$^{c2}$ | 4.76±0.10$^{c2}$ | 5.02±0.11$^{b2}$ | 6.24±0.11$^{a2}$ |
| SRF | 4.48±0.06$^{d}$ | 4.59±0.11$^{c2}$ | 4.75±0.14$^{b2}$ | 5.04±0.17$^{b2}$ | 6.10±0.12$^{a2}$ |
| JSF | 4.52±0.11$^{d}$ | 4.68±0.10$^{c2}$ | 4.84±0.12$^{b2}$ | 4.98±0.11$^{b2}$ | 6.20±0.14$^{a2}$ |
| TPF | 4.57±0.06$^{d}$ | 4.82±0.11$^{c1}$ | 4.92±0.14$^{c1}$ | 5.35±0.17$^{b1}$ | 6.50±0.12$^{a1}$ |
| **Psychrotropic count (log cfu/g)** | | | | | |
| Control | ND | ND | 2.69±0.11$^{c2}$ | 3.12±0.14$^{b2}$ | 4.15±0.14$^{a2}$ |
| SRF | ND | ND | 2.67±0.14$^{c2}$ | 3.15±0.10$^{b2}$ | 4.09±0.11$^{a2}$ |
| JSF | ND | ND | 2.72±0.11$^{c2}$ | 3.23±0.12$^{b2}$ | 4.22±0.11$^{a2}$ |
| | ND | ND | 2.96±0.14$^{c1}$ | 3.67±0.10$^{b1}$ | 4.59±0.11$^{a1}$ |
| **Coliform count (log cfu/g)** | | | | | |
| Control | ND | ND | 1.10±0.12$^{c}$ | 1.34±0.10$^{b2}$ | 1.98±0.10$^{a2}$ |
| | ND | ND | 1.11±0.12$^{c}$ | 1.38±0.11$^{b2}$ | 1.89±0.10$^{a2}$ |
| | ND | ND | 1.16±0.10$^{c}$ | 1.41±0.12$^{b2}$ | 1.95±0.12$^{a2}$ |
| | ND | ND | 1.15±0.12$^{c}$ | 1.58±0.11$^{b1}$ | 2.12±0.10$^{a1}$ |
| **Lactobacillus count (log cfu/g)** | | | | | |
| Control | 2.32±0.10$^{e}$ | 2.54±0.11$^{d2}$ | 2.70±0.10$^{c2}$ | 2.82±0.14$^{b2}$ | 2.93±0.11$^{a2}$ |
| | 2.42±0.14$^{d}$ | 2.53±0.12$^{c2}$ | 2.75±0.10$^{b2}$ | 2.84±0.11$^{b2}$ | 2.97±0.10$^{a2}$ |
| JSF | 2.48±0.12$^{d}$ | 2.62±0.10$^{c1}$ | 2.80±0.10$^{b12}$ | 2.91±0.14$^{a2}$ | 2.99±0.10$^{a2}$ |
| TPF | 2.43±0.14$^{e}$ | 2.70±0.12$^{d1}$ | 2.92±0.10$^{c1}$ | 3.11±0.11$^{b1}$ | 3.27±0.10$^{a1}$ |
| **Staphylococcus aureus count (log cfu/g)** | | | | | |
| Control | ND | ND | 2.30±0.14$^{c3}$ | 2.95±0.14$^{b2}$ | 3.23±0.12$^{a2}$ |
| SRF | ND | ND | 2.36±0.17$^{c23}$ | 2.88±0.10$^{b2}$ | 3.25±0.17$^{a2}$ |
| JSF | ND | ND | 2.40±0.17$^{c2}$ | 2.97±0.14$^{b2}$ | 3.30±0.14$^{a2}$ |
| TPF | ND | ND | 2.55±0.17$^{c1}$ | 3.18±0.10$^{b1}$ | 3.49±0.17$^{a1}$ |
| **Yeast and mold count (log cfu/g)** | | | | | |
| Control | ND | 1.55±0.12$^{d2}$ | 1.82±0.11$^{c2}$ | 1.96±0.14$^{b2}$ | 2.31±0.12$^{a2}$ |
| SRF | ND | 1.58±0.14$^{d2}$ | 1.80±0.12$^{c2}$ | 1.97±0.14$^{b2}$ | 2.29±0.10$^{a2}$ |
| JSF | ND | 1.57±0.10$^{d2}$ | 1.81±0.12$^{c2}$ | 1.93±0.10$^{b2}$ | 2.33±0.10$^{a2}$ |
| TPF | ND | 1.68±0.14$^{d1}$ | 1.94±0.12$^{c1}$ | 2.17±0.14$^{b1}$ | 2.59±0.10$^{a1}$ |

n=9; *ND- Not Detected

SRF- Sticky rice flour; JSF- Jackfruit seed flour; TPF- Tapioca flour

Means with different superscripts (letters in the same row and numbers in the same column) indicate significant difference ($P<0.05$)

Tyrosine values did not differ significantly (P>0.05) among treatment groups on the day of processing, while it increased in all the groups during the subsequent storage period and the increase was more significant (P<0.05) in nuggets containing tapioca flour. This increase in tyrosine values with the advancement of storage period could be attributed to the increased rate of proteolysis occurred in the products as a result of increase in microbial load (Table 4) and the significantly higher microbial load observed in the nuggets with tapioca flour could probably explain the reason for the higher tyrosine values observed in it. Similarly, titratable acidity did not differ significantly (P>0.05) among treatments on the day of processing (Table 3). All the samples showed a reduction in titratable acidity on day 7, while it increased on day 14, but further decreased from day 21 onwards. The decrease in titratable acidity of nuggets on day 7 could be attributed to their increased pH (Table 3). The lactic acid produced by increased lactobacillus organisms (Table 4) might have resulted in an increase in titratable acidity on day 14. The further reduction in titratable acidity on day 21 onwards could be due to increased accumulation of bacterial metabolites as a result of a substantial increase in total plate count (Table 4), masking the effect of increased lactobacillus counts (Lawrie, 1998).

***Microbiological and sensory characteristics:*** Incorporation of different flours in place of wheat flour had no significant (P>0.05) effect on any of the enumerated microbial population in pork nuggets on the day of processing. With the elapse of storage time, the total viable count had shown significant increase (P<0.05) in all the groups and on day 28, the counts were not only reached above 6.0 log10 cfu/g but sliminess was also appeared on the products. As mentioned above pH and TBARS values were also reached to unacceptable levels on 28th day of storage and the sensory analysis on that day revealed that the products were spoiled (Table 5). It has been reported that spoilage of meat products is not noticed until bacterial counts are more than 108 cells/cm2 (Jay 1996), however, in this study, spoilage of pork nuggets was detected at bacterial counts below 7 log cfu/g. Psychrotropic organisms, coliforms, Staphylococcus aures and yeast & molds were not detected in any of the samples on the day of processing and this might be attributed to a retardation of the log phase as a result of reduced metabolic rate due to a sudden change in the physical environment (Lawrie 1998). As mentioned in case of total viable counts, these organisms were also shown significant increase (P<0.05) in their counts with the advancement of storage period and the rate of increase was slightly higher in the nuggets containing tapioca flour.

Sensory evaluation of the stored nuggets was performed only up to 21st day due to the development of sliminess and slight off flavour in the products on day 28 (Table 5). The panelists had significantly (P<0.05) higher liking for the appearance and colour of the nuggets containing sticky rice flour throughout the storage period. As mentioned above, the instrumental colour evaluation using hunter colour lab also indicated significantly higher lightness (L*) values in the nuggets containing sticky rice flour (Table 1) and the sensory evaluation scores further indicated that the panelists had more preference for the lightness resulted in the products from the sticky rice flour addition.

**Table 5: Effect of addition of sticky rice powder, jackfruit seed powder and tapioca flour on the sensory attributes* of pork nuggets during refrigeration storage.**

| Treatment/ Parameter | Storage period (days) | | | | |
|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 |
| **Appearance and colour** | | | | | |
| Control | $7.50{\pm}0.14^{a2}$ | $7.50{\pm}0.13^{a2}$ | $7.00{\pm}0.19^{b2}$ | $6.50{\pm}0.16^{c2}$ | SP |
| SRF | $8.00{\pm}0.19^{a1}$ | $8.00{\pm}0.14^{a1}$ | $7.50{\pm}0.13^{b1}$ | $7.00{\pm}0.14^{c1}$ | SP |
| JSF | $7.50{\pm}0.13^{a2}$ | $7.50{\pm}0.16^{a2}$ | $7.00{\pm}0.18^{b2}$ | $6.50{\pm}0.15^{c2}$ | SP |
| TPF | $7.00{\pm}0.19^{a3}$ | $7.00{\pm}0.14^{a3}$ | $6.50{\pm}0.13^{b3}$ | $6.00{\pm}0.14^{c3}$ | SP |
| **Flavour** | | | | | |
| Control | $7.50{\pm}0.14^{a1}$ | $7.50{\pm}0.13^{a1}$ | $7.00{\pm}0.19^{b1}$ | $6.50{\pm}0.16^{c1}$ | SP |
| SRF | $7.50{\pm}0.19^{a1}$ | $7.50{\pm}0.14^{a1}$ | $7.00{\pm}0.13^{b1}$ | $6.50{\pm}0.14^{c1}$ | SP |
| JSF | $7.50{\pm}0.13^{a1}$ | $7.50{\pm}0.16^{a1}$ | $7.00{\pm}0.18^{b1}$ | $6.50{\pm}0.15^{c1}$ | SP |
| TPF | $7.00{\pm}0.19^{a2}$ | $7.00{\pm}0.14^{b2}$ | $6.50{\pm}0.13^{c2}$ | $5.50{\pm}0.14^{d2}$ | SP |
| **Juiciness** | | | | | |
| Control | $7.50{\pm}0.18^{a1}$ | $7.50{\pm}0.13^{a1}$ | $7.00{\pm}0.19^{b1}$ | $6.50{\pm}0.15^{c1}$ | SP |
| SRF | $7.50{\pm}0.19^{a1}$ | $7.50{\pm}0.15^{a1}$ | $7.00{\pm}0.15^{b1}$ | $6.50{\pm}0.19^{c1}$ | SP |
| JSF | $7.50{\pm}0.16^{a1}$ | $7.50{\pm}0.18^{a1}$ | $7.00{\pm}0.18^{b1}$ | $6.50{\pm}0.11^{c1}$ | SP |

| | | | | | |
|---|---|---|---|---|---|
| TPF | $7.00\pm0.15^{a2}$ | $7.00\pm0.16^{a2}$ | $6.50\pm0.19^{b2}$ | $6.00\pm0.14^{c2}$ | SP |
| **Texture** | | | | | |
| Control | $7.50\pm0.18^{a1}$ | $7.50\pm0.16^{a1}$ | $7.00\pm0.19^{b1}$ | $6.00\pm0.16^{c1}$ | SP |
| SRF | $7.50\pm0.11^{a1}$ | $7.50\pm0.14^{a1}$ | $7.00\pm0.15^{b1}$ | $6.00\pm0.15^{c1}$ | SP |
| JSF | $7.50\pm0.15^{a1}$ | $7.50\pm0.19^{a1}$ | $7.00\pm0.18^{b1}$ | $6.00\pm0.15^{c1}$ | SP |
| TPF | $7.00\pm0.15^{a2}$ | $6.50\pm0.15^{b2}$ | $6.50\pm0.15^{b2}$ | $5.50\pm0.18^{c2}$ | SP |
| **Binding** | | | | | |
| Control | $7.50\pm0.19^{a1}$ | $7.50\pm0.15^{a1}$ | $7.00\pm0.19^{b1}$ | $6.00\pm0.16^{c1}$ | SP |
| SRF | $7.50\pm0.19^{a1}$ | $7.50\pm0.15^{a1}$ | $7.00\pm0.15^{b1}$ | $6.00\pm0.18^{c1}$ | SP |
| JSF | $7.50\pm0.15^{a1}$ | $7.50\pm0.16^{a1}$ | $7.00\pm0.18^{b1}$ | $6.00\pm0.15^{c1}$ | SP |
| TPF | $7.00\pm0.17^{a2}$ | $6.50\pm0.14^{b2}$ | $6.50\pm0.15^{b2}$ | $5.50\pm0.14^{c2}$ | SP |
| **Overall acceptability** | | | | | |
| Control | $7.50\pm0.15^{a2}$ | $7.50\pm0.15^{a2}$ | $7.00\pm0.19^{b2}$ | $6.50\pm0.16^{c2}$ | SP |
| SRF | $8.00\pm0.16^{a1}$ | $8.00\pm0.14^{a1}$ | $7.50\pm0.15^{b1}$ | $7.00\pm0.14^{c1}$ | SP |
| | $7.50\pm0.15^{a2}$ | $7.50\pm0.16^{a2}$ | $7.00\pm0.18^{b2}$ | $6.50\pm0.15^{c2}$ | SP |
| | $7.00\pm0.19^{a3}$ | $7.00\pm0.19^{a3}$ | $6.50\pm0.15^{b3}$ | $6.00\pm0.19^{c3}$ | SP |

n=21; SP- Spoiled
*Based on 8-point descriptive scale
SRF- Sticky rice flour; JSF- Jackfruit seed flour; TPF- Tapioca flour
Means with different superscripts (letters in the same row and numbers in the same column) indicate significant difference (P<0.05)

Panelists could not find any significant difference (P>0.05) for flavor, juiciness, texture and binding of nuggets containing wheat flour (control), sticky rice flour and jackfruit seed flour. However, the above parameters were rated significantly low (P<0.05) for the nuggets containing tapioca flour and this might be attributed to the significantly low fat and water binding properties observed in it (Table 1). The results also indicated that, the overall acceptability scores were mainly influenced by the appearance and texture attributes of the products.

## CONCLUSION

Incorporation of sticky rice flour and jackfruit seed flour in the formulation of processing pork nuggets to completely replace wheat flour as filler had no significant effect on any of the important physico-chemical, microbiological and sensory parameters of the finished products. Products containing sticky rice flour did show even some of the better quality parameters viz. emulsion stability, textural properties and product colour as evaluated both by instrument and trained panelists, compared to that containing wheat flour. Also, complete replacement of wheat flour with tapioca flour in the formulation resulted in significant reduction in most of the physico-chemical and sensorial properties of pork nuggets. It is concluded that pork nuggets could be processed by completely replacing wheat flour with sticky rice flour and jackfruit seed flour as fillers at 3.5% level and the products thus processed retained 'very good' to 'good' acceptability range up to 21st day of storage at refrigeration temperature.

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