Value added products with popular low grade rice varieties of Andhra Pradesh

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Abstract Eight Popular Low Grade Rice Varieties (PLRVs) MTU 3626, MTU 1001, MTU 1010, MTU 4870 and NLR 145, NLR 34242, NLR 30491, NLR 34449, (developed and released by ANGR agricultural University, Andhra Pradesh) having poor cooking quality were selected for the study. ANGRAU variety BPT 5204 popularly consumed as staple rice was used as check. Eight products of traditional/commercial importance were standardized incorporating PLRVs as a major ingredient in the form of rice flour (burfi, noodles and extruded snack product and vennaundalu (butter coated balls), palathalikalu (dough rolled into strips, steamed/cooked in milk); rice semolina (instant kheer mix and instant upma mix), and flaked rice (nutritious bar). The products were evaluated for nutritional, cooking quality characteristics, consumer acceptability and shelf-life. Consumer acceptability of the PLR products was carried out with 60 farm women based on 9 point hedonic scale. Shelf-life of the products (packed in both metalized PP and PE pouches) was evaluated monthly for chemical, microbiological and sensory parameters. Energy values of control and PLR products showed no significant difference. Upon cooking, PLR Noodles showed no significant difference with water absorption and volume but more ($p < 0.05$) solid loss and cooked weight. Utilization of PLR flakes in nutritious bar resulted in highly crispy and crunchy texture, enhanced flavor and taste as compared to control. The percent total solids and suspended solids were more (though not significant) in PLR kheer and palathalikalu. Extruded product (control and PLR) showed no significant difference with

length, diameter, weight and volume expansion ratio and water absorption index (WAI). Consumer acceptability was high for PLR products palathalikalu (95%), instant kheer mix (92%) and extruded product (88%). As per sensory scores, all the PLR products were well accepted with no observable changes in flavor or taste upon storage. PLR products showed increased ($P < 0.05$) trend for moisture and FFA content from initial to 90 days of storage. The lowest TPC was observed for noodles and highest for burfi (though in safe limits). Extruded snacks (control and PLR) showed no microbial growth during the entire storage period. Considering the poor marketability of PLRVs for consumption as staple rice, the study signifies the utilitarian value of PLRVs in making products of convenience/commercial importance.

Keywords Popular low grade rice varieties (PLRVs) · Product development · Convenience foods · Product quality · Consumer acceptability · Shelf life

Domestication of rice (*Oryza sativa* L) by humans that occurred more than 10,000 years ago led to a series of developments in rice culture over millennia, making it the most important staple food crop for more than half of the world's population (Ashwini et al. 2008). It has many diverse uses and is consumed in many forms. In India, it is an important source of food as well as source of income to the farming community. Andhra Pradesh is a surplus rice growing state, with cultivated area of 39.46 lakh ha and average productivity of 3352 kg/ha during the year 2007–08 (Directorate of Economics and Statistics 2008). Rice is grown in almost all parts of the state in all seasons and in all kinds of soils, and is rightly called as “Annapurna state”, “Rice bowl of India” and “Granary of south India”. Rice grain quality is an important criteria after yield, which affects

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domestic consumption and possibly international trade. Less attractive grain characteristics hamper the acceptance and spread of varieties (Shobha Rani et al. 2008). Many rice hybrids/high yielding varieties had been released by Acharya N.G.Ranga Agricultural University for cultivation in Andhra Pradesh. Some of the varieties though well known and popular for their high yields are not preferred for consumption at household level due to their poor cooking quality, coarse grains type and hence are rated as common or low grade rice varieties (ANGRAU 2004; Bhashyam et al. 2006). However, many south Indian rice varieties are reported to be non sticky and harder upon cooking and has an intermediate gelatinization temperature (72–74 °C) (Bhattacharya et al. 1980). Various processed products can be produced with rice which upgrades the quality (Juliano 1990). Traditional rice products in developing countries are small scale and have short shelf life. Improvement of value added traditional rice products selected based on marketability and profitability will create jobs in rural areas and make a country's products compete globally as import substitute or as exports to niche markets (Toriyama et al. 2005).

Countries like Japan, China and United States have been successful in developing and using a variety of commercial rice based products like pre cooked, convenience products, extruded products, noodles, canned products and traditional products (Toriyama et al. 2005). About 14.46 million tones (10% of the production) is being utilized for the production of rice based products in the country (Chitra et al. 2010). Value added products such as quick cooking rice, instant rice noodles, cocoa powder coated rice flakes, rice bread are said to be popular in Kerala (Anon 2007). The unique properties of rice such as hypo-allergenicity and bland taste make it desirable for diverse food product development. Development of value added products using PLRVs will benefit farmers in income generation and sustainability of the varieties. The present study therefore had been taken up to develop acceptable ready to eat and convenience products of traditional/commercial importance.

Materials and methods

Procurement of Paddy samples Eight PLRVs MTU 3626, MTU 1001, MTU 1010 and MTU 4870 (from Regional Agricultural Research Station, Maruteru, West Godavari district) and NLR 145, NLR 34242, NLR 30491 and NLR 34449 (from Agricultural Research Station, Nellore district) were procured during the month of August, 2008 in the quantity of 20–25 kg(6 months old).

Method of milling The percentages of hulling, milling of the rice varieties were assessed following the procedures of Govindaswamy and Ghosh (1969).

Sensory evaluation of PLRVs Five grams each rice sample (Check variety and PLRVs) was taken in test tube 13–14 ml water was added and soaked for 10 min. The test tube containing rice was placed on a water bath cooked for 15–16 min till total water gets absorbed by the grains (water is not drained) and transferred into a Petri dish, and subjected to sensory characteristics. A score card was prepared keeping in view the specific quality attributes of rice following the Laboratory manual on rice grain quality procedures (DRR 2004).

Products with PLRVs Eight popular and commercially viable ready-to-eat and ready-to-cook products were standardized incorporating PLRVs as a major ingredient in the form of rice flour (burfi, noodles and extruded snack product and traditionally popular *vennaundalu* (butter coated balls), *palathalikalu* (dough rolled into strips, steamed/cooked in milk); rice semolina (instant kheer mix and instant upma mix), flaked rice (nutritious bar)

Burfi Ingredients Bengal gram flour 100 g, vanaspathi 70 ml, condensed milk 25 ml, powdered sugar 100 g, ground cardamom 1 g, fried cashew nuts 6 g and fried almonds 2 g.

PLR burfi was prepared by blending Bengal gram flour and rice flour (PLRV MTU 1010) flour in the proportion of 100:0, 50:50, 25:75 and 0:100.

Bengal gram flour was roasted with vanaspathi in an aluminum pan and with continuous mixing. The final temperature of the roasts was allowed to rise up to 140–165 °C. The roasts were allowed to cool to 115 °C and condensed milk was added and mixed thoroughly. The mixture was again heated till the temperature reached 120 °C and mixed with powdered sugar, cardamom, fried cashew nuts and almonds. The contents were thoroughly mixed, poured in greased aluminum trays, rolled and cut into slabs.

Butter coated balls Ingredients: rice flour 100 g, ghee 20 g, banana 14 g, sesame seeds 3 g, hydrogenated oil 250 ml, sugar 67 g, water 55 ml and ground cardamom 1 g.

PLR *butter coated balls* were prepared using PLRVs NLR 30491 flour in the proportion of 100:0, 50:50, 25:75 and 0:100.

Rice flour was mixed with melted ghee, banana and sesame seeds. Dough was prepared with required water and kept aside for 3 h. Prepared semi-circle type balls with 1 g small dough and were deep fried in hydrogenated oil. Sugar syrup (thin consistency stage) was made and ground cardamom was added. Fried balls were poured in prepared syrup; keep for 1 min and pack.

Nutritious bar Ingredients: Corn flakes 50 g, oat flakes 50 g, Jaggery 400 g, almonds 25 g, raisins 2 g, dry dates 50 g, acacia gum 3 g and ghee 5 g.

PLR *nutritious bar* was prepared by using PLRV MTU 3626 flakes in the proportion of 100:0, 50:50, 25:75 and 0:100.

Flakes were ground and fried in ghee. Jaggery syrup was prepared (threading stage) and powdered acacia gum was added. Boiling was continued till soft ball stage. Then, Flakes and chopped nuts (almonds, dates & raisins) were added to syrup. Mixture was poured on a pre-greased flat surface, cooled and cut into pieces.

Instant palathalikalu Ingredients: rice flour 100 g (popularly consumed BPT 5204) desiccated coconut 15 g, sugar 8 g, salt 1 g, water 60 ml and ground cardamom 2 g. fried cashew nut pieces(4–5), raisins (a few)

PLR *palathalikalu* was prepared using PLRV, NLR 34242 flour in the proportion of 100:0, 50:50, 25:75 and 0:100.

Rice flour was mixed with desiccated coconut powdered sugar, salt, ground cardamom. Dough was prepared with required water and kept aside for 1 h. The dough was made into elongated strips of 1–2 cm. The moulds were shade dried at room temperature (10–15 min) and then, dried in oven (50 °C) for 2 days to moisture level below 7%.

Dried *palathalikalu* (50 g) were added to 250 ml boiling milk and cooked for 10 min. 20 g of powdered jaggery, ground cardamom, fried cashew nut pieces and raisins were added to the above mixture and continued cooking for further 5 min (till the mixture becomes thick in consistency).

Instant kheer mix Ingredients: Rice (BPT 5204 variety), semolina 100 g, powdered sugar 100 g, skimmed milk powder 115 g, vanaspathi 15 ml, ground cardamom 1.5 g, cashew nuts and raisins each 20 g.

PLR kheer mix was prepared by replacing PLRV MTU 1001 semolina in the proportion of 100:0, 50:50, 25:75 and 0:100.

Fat was melted in non-stick pan and rice semolina was added to hot fat. Roasted semolina 110–125 °C (till golden yellow in colour) and cooled at room temperature. Cashew nut pieces and raisins were roasted in little fat at 120 °C for 15 s to golden brown colour). All the dry ingredients and skim milk powder were mixed uniformly and 3–4 strands of saffron and cardamom powder were added.

100 g of the mix was dispersed in 50 ml boiling water and boiling was continued for 5–10 min with constant stirring.

Instant upma mix Ingredients: Wheat semolina 100 g, Bengal gram dhal 2 g, mustard seeds 0.5 g, dried curry leaves 2 g, dried green chillies 0.8 g, dried ginger 0.6 g, salt 3 g, citric acid 0.2 g and vanaspathi 10 ml.

PLR upma was prepared by blending wheat semolina and PLRV NLR 34449 semolina in the proportion of 100:0, 50:50, 25:75 and 0:100.

Vanaspathi was heated in non-stick pan at 180 °C. Bengal gram and mustard seeds dehydrated curry leaves, chillis, ginger were added and roasted for 1 min. Semolina, salt, citric

acid were added to the seasonings and roasted on low flame for 5 min. Cooled at room temperature.

300 ml of water was kept for boiling (covered for preventing evaporation losses) & 1 tsp Hydrogenated fat was added. The instant dry mix was added slowly with constant stirring till all the water was absorbed. The upma was garnished with green coriander leaves.

Noodles Ingredients: Refined wheat flour 100 g, hydrogenated fat 8 g, GMS 1 g, salt 0.5 g, and water 55 ml.

PLR noodles was prepared by blending refined wheat flour and PLRV MTU 4870 flour in the proportion of 100:0, 50:50, 25:75 and 0:100.

The fat was melted and mixed into the flour. All the dry ingredients were added and mixed well. The required amount of water (50 °C) was added and kneaded for 10–15 min to obtain dough of optimum consistency. The dough was extruded into noodles by using a manual single screw hand press. The noodles were pre-dried for 30 min. at 80 °C and steamed at 100 °C for 4–5 min. The steamed noodles were finally dried at 60–70 °C for 3–4 h or till the noodles attained moisture <10% and packed.

Two cups of water were boiled and 1 tsp. of edible oil and salt (if desired) was added. The dried noodles were added to the boiling water and cooked for 8–10 min. The cooked noodles were strained through a sieve and held under cold running water to avoid stickiness. The cooked noodles were served with sauce after garnishing with fresh chopped vegetables sauted in little oil

Extruded snack product Ingredients: rice (BPT 5204 variety) flour 100 g, defatted soy flour 15 g, salt 0.5 g, water 20 ml and any spice mix 5 g. PLR extruded snacks was prepared by blending BPT 5204 rice flour and PLR (NLR 145 variety) flour in the proportion of 100:0, 50:50, 25:75 and 0:100.

Rice flour and salt was blended thoroughly and passed through 40-mesh sieve, mixed well. Flour was wetted with water (moisture content 11%) and packed in poly ethylene pouches. The bags were kept for conditioning at 4 °C for 12 h. Extrusion was performed in a co-rotating screw extruder (DS32-II, Jinan Saixin Food Machinery, China), consisting of three independent zones of controlled temperature in the barrel. The length to diameter (L/D) ratio for the extruder was 20:1. The diameter of the hole in the die was 6 mm with a die of length 27 mm. The temperature profiles on the feed and compression metering zones were kept constant at 60 and 70 °C respectively and the die head temperature were 110 °C. The mixture was passed through extruder and the product was cut with a face cutter as they left the extrusion die. After stable conditions were established, extrudates were collected and dried in air oven at 50 °C for 16 h attaining moisture of <7%.

Sensory evaluation of the PLR products The different PLR products were evaluated to find the maximum acceptable level of incorporation by a panel of 10 semi-trained judges using 5 – point Hedonic scale following the method of Amerine et al. (1965). The products were evaluated for their appearance & colour, texture, taste, flavor and overall acceptability.

Assessment of quality parameters in the PLR products

Noodles Determination of minimum cooking time (min) was done by placing 10 g noodles in a beaker containing 200 ml of distilled water and heating in boiling water bath. After every 30 s a piece of noodle was taken out and squeezed in between 2 glass slides. When the white core just disappeared, the time taken for cooking was recorded as minimum cooking time. Percent water uptake or water absorption (ml/100 g) was determined as per BIS (1976) method. To estimate total solid loss/gruel solids (%), cooked water drained earlier in a flask was made to 250 ml volume using distilled water and 10 ml was poured to pre-weighed Petri dish and evaporated to dryness in an air oven at 100 ± 1 °C overnight. Weight was noted after keeping it in desiccators. The total and suspended solids in the kheer were determined by the methods outlined in the ISI Handbook of Food analysis, 1981. The total solid was determined by subtracting from 100, the moisture content in the kheer.

To determine the suspended solid content, the kheer was passed through a muslin cloth and the solid retained on the cloth was estimated gravimetrically.

Volume increase upon cooking It was estimated as per the procedure of Sowbhagya and Zakiruddin Ali (2001). Volumes of the dry & cooked noodles were measured by water-displacement method and increase in volume was recorded.

Determination of total and suspended solids of kheer and palathalikalu was done following the methods outlined in the ISI Handbook of Food analysis (1974).

Extruded snack product Length (mm) and diameter (mm) of 10 extruded samples (Control & PLRV) were measured using Vernier Caliper (Satak Company) weight of the samples was measured with weighing balance (Satak Company). Volume expansion ratio was calculated as the ratio between the average diameter of 10 extrudes samples and the die diameter. Water absorption index (WAI) was determined using the method of described by Mercier and Feillet (1975).

The selected PLR and control products were calculated for nutrients based on Nutritive Value of Indian Foods (Gopalan et al. 2004). Carbohydrate content was calculated

by difference i.e. 100 minus the sum of percentages of moisture, fat, protein, crude fibre and ash. The energy value was computed indirectly using the formula i.e.

Total calories = (4x Carbohydrate content) + (4x Protein content) + (9x Fat content) and was calculated to the nearest value.

Consumer acceptability studies Sixty farm women were asked to evaluate the products based on 9 point Hedonic scale (Larmond 1977) i.e. 1 to 9 (9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely) and their responses were recorded.

Storage studies The PLR products were packed in metalized polypropylene pouches (MPP) and poly-ethylene pouches (PEP) having a thickness of 40 µm and stored at room temperature (28 ± 2 °C). Storage stability of the products was assessed by determining moisture and free fatty acid contents (AOAC 1990), total viable bacterial count (Cruick et al. 1975) and sensory quality parameters based on 5-point Hedonic scale (Amerine et al. 1965) at monthly intervals for a period of 3 months.

Statistical analysis The data pertaining to sensory evaluation and effect of storage on shelf life of the products was analyzed using the analysis of variance (ANOVA) technique while paired *t*-test was used to compare cooking quality parameters between the control and PLR incorporated products (Snedecor and Cochran 1989). All the products were analyzed in triplicate.

Results and discussion

Sensory attributes aroma, flavor, taste, tenderness or hardness, cohesiveness or stickiness, appearance all influence the eating quality (Mundey et al. 1989). In the present study, check variety obtained significantly higher ($P < 0.05$) scores for all the sensory attributes than PLRVs (Table 1). Factors like starch - protein interactions and arrangement of amylose molecules, use of organic manure like farmyard and green manure (Priyadarsini and Prasad 2003) might have affected tenderness, taste and arrangement of amylose molecules which in turn said to affect palatability. Much emphasis has been placed on the improvement of eating and cooking quality of rice but it is not clear what factors affect these properties. The content of amylose, which is defined as a ratio to the total amount of starch, is widely reported to be as one of the major determinants of cooking and eating qualities of rice grain (Zhout et al. 2002) Low amylase content is generally associated with tender, sticky and glossy cooked rice, while high amylase content is associated with firm,

Table 1 Sensory characteristics of popular low grade rice varieties (PLRVs)

Name of the Variety	Appearance	Cohesiveness	Tenderness on touching	Tenderness on chewing	Taste	OAA*	As per rating terms
Check variety							
BPT 5204	4.8±0.42 ^a	4.5±0.46 ^a	4.6±0.35 ^a	4.6±0.46 ^a	4.8±0.67 ^a	4.6±0.35 ^a	Very Good
PLRVs							
MTU 3626	3.5±0.35 ^{cd}	3.5±0.48 ^{de}	2.4±0.46 ^{fg}	1.9±0.48 ^e	2.4±0.48 ^{bc}	2.2±0.48 ^{de}	Fair
MTU 4870	4.4±0.52 ^b	3.3±0.49 ^{de}	3.6±0.54 ^c	2.9±0.48 ^b	3.2±0.46 ^b	2.7±0.54 ^{cd}	Fair
MTU 1001	3.5±0.48 ^{cd}	3.6±0.54 ^d	2.4±0.48 ^d	2.6±0.67 ^{cd}	2.8±0.54 ^{bc}	2.7±0.48 ^{cd}	Fair
MTU 1010	3.4±0.54 ^{cd}	3.8±0.49 ^c	2.1±0.67 ^h	2.3±0.54 ^{cd}	2.5±0.49 ^{bc}	2.4±0.67 ^{cd}	Fair
NLR 145	3.7±0.54 ^c	3.4±0.48 ^{de}	2.7±0.48 ^{de}	2.7±0.48 ^{cd}	2.6±0.48 ^{bc}	2.5±0.35 ^{cd}	Fair
NLR 30491	3.6±0.48 ^d	3.5±0.35 ^{de}	3.0±0.35 ^c	2.7±0.35 ^{cd}	2.5±0.54 ^{bc}	2.7±0.67 ^c	Fair
NLR 34242	3.1±0.46 ^e	3.3±0.49 ^{de}	2.8±0.67 ^{cd}	2.4±0.49 ^{cd}	3.0±0.35 ^{bc}	2.5±0.49 ^{cd}	Fair
NLR 34449	3.7±0.46 ^{cd}	4.1±0.67 ^b	3.6±0.35 ^b	3.8±0.49 ^a	3.1±0.49 ^{bc}	3.3±0.49 ^b	Good
CD	0.23	0.20	0.28	0.37	0.38	0.33	—

Values with different superscript column wise differ significantly ($P<0.05$), ($n=3$).

(Each mean is the average of 3 independent values obtained in three different days)

^a to ^h Significantly different from their corresponding check value ($P<0.05$)

*OAA - Over all Acceptability

fluffy and separate grains of cooked rice (Ong and Blanshard 1995). Substantial evidence indicates that high amylase content in rice grain would cause reduction in palatability of rice, especially in stickiness (Ramesh et al. 1999). Meullenet et al. (1998) reported that rice texture is affected by factors such as rice variety, amylose content, gelatinization temperature and processing factor.

Sensory quality of PLR products The acceptable levels of incorporation of PLRVs into the products were 75% for burfi, nutritious bar, ready to cook noodles and 100% for traditionally popular *vannaundalu* (butter coated balls) and ready to cook *palathalikalu*, instant kheer mix, instant upma mix, and ready to eat extruded snack product (Table 2). One hundred percent incorporation of PLR flour resulted in burfi that was hard in texture, dry mouth feel and difficult to breakdown. This may be due to less fat absorption by rice flour than besan which is the basic ingredient in control recipe. In case of nutritious bar, 75% incorporation of PLR flakes was found result in highly desirable qualities like crispy and crunchy texture, pleasant flavor and very good taste than higher levels (100%) of incorporation. Higher levels of incorporation of PLR flour (above 75%) resulted in noodles with brittleness or grittiness and difficult to extrude and susceptible to breakage. This may be due to the fact that increased level of PLR flour cuts down the percentage of wheat flour and hence gluten percentage, protein in the noodles which reduce the strength of noodles. Higher levels (100%) of incorporation of rice in noodles reported to affect product properties through ungelatinization of starch molecule and also various factors apart from

starch and protein said to affect the texture of noodles were ratio of amylose, amylopectin and gluten content (Toriyama et al. 2005).

Assessment of quality parameters in the PLR products Noodles (Control and PLR) cooked showed no significant difference with regard to water absorption, volume after cooking but as compared to control PLR noodles showed significantly higher ($p<0.05$) solid losses (6.35%) and cooked weight upon cooking (3.2) (Table 3). The reduction in cooked weight of PLR noodles might be due to increase in total solid losses after cooking. Sudha et al. (1998) also noted similar results while working with blends of finger millet and semolina. However, the solid losses for both control and PLR noodles was within the BIS norms (BIS:1476-1985) and as reported to not exceed 10% (Matz 1991).

Kheer and Palathalikalu Percent total solids and suspended solids were more in case of PLR kheer and *palathalikalu* as compared to control product though not significant ($P<0.05$) (Table 3). This may be due to lesser moisture in the PLR kheer mix and *palathalikalu* as compared to control products & since both were cooked in equal amounts of water, the same was reflected in the total solid content of prepared kheer.

Extruded snack product Extruded product (control & PLR) showed no significant difference with regard to length, diameter, weight and volume expansion ratio and water absorption index (WAI) though the values for control extruded product were on higher side (Table 3). This is because check variety has high volume expansion ratio than all PLRVs studied. Volume

Table 2 Sensory scores for products with different levels of PLRVs*

Products	PLR incorporation,%	Appearance	Texture	Taste	Flavour	Overall acceptability
Burfi	0	4.8±0.42 ^a	4.9±0.16 ^a	4.7±0.48 ^a	4.7±0.48 ^a	4.8±0.24 ^a
	50	4.7±0.48 ^a	4.8±0.48 ^a	4.6±0.67 ^a	4.6±0.70 ^a	4.7±0.54 ^a
	75	4.7±0.48 ^a	4.8±0.52 ^a	4.7±0.42 ^a	4.6±0.70 ^a	4.7±0.49 ^a
	100	4.1±0.32 ^b	3.8±0.42 ^b	4.0±0.69 ^b	3.4±0.52 ^b	3.9±0.82 ^b
CD at 5%	0.33	0.36	0.32	0.36	0.35	
Butter coated balls	0	4.6±0.52 ^a	4.9±0.32 ^a	4.6±0.41 ^b	4.6±0.46 ^a	4.6±0.52 ^a
	50	4.0±0.33 ^c	4.6±0.46 ^b	4.4±0.48 ^{ab}	4.3±0.63 ^b	4.4±0.57 ^b
	75	4.3±0.54 ^b	4.6±0.46 ^b	4.4±0.48 ^{ab}	4.3±0.67 ^b	4.5±0.53 ^{ab}
	100	4.5±0.82 ^a	4.8±0.42 ^a	4.6±0.42 ^a	4.5±0.47 ^a	4.6±0.52 ^a
CD at 5%	0.19	0.14	0.26	0.14	0.12	
Nutritious bar	0	4.8±0.42 ^a	4.5±0.00 ^a	4.7±0.54 ^a	4.4±0.52 ^a	4.5±0.53 ^a
	50	4.4±0.52 ^b	4.2±0.46 ^b	4.3±0.42 ^b	4.3±0.48 ^a	4.2±0.42 ^b
	75	4.4±0.52 ^b	4.2±0.46 ^b	4.3±0.42 ^b	4.3±0.48 ^a	4.2±0.35 ^b
	100	4.3±0.48 ^b	4.0±0.52 ^c	3.6±0.52 ^c	4.1±0.32 ^a	3.8±0.42 ^c
CD at 5%	0.36	0.25	0.35	0.32	0.29	
Instant Palathalik- alu	0	4.8±0.16 ^a	4.7±0.32 ^b	4.8±0.41 ^a	4.6±0.26 ^a	4.6±0.52 ^a
	50	4.8±0.13 ^a	4.6±0.36 ^{bc}	4.7±0.48 ^{ab}	4.6±0.23 ^a	4.6±0.59 ^{ab}
	75	4.8±0.24 ^a	4.6±0.26 ^{bc}	4.7±0.48 ^{ab}	4.6±0.27 ^a	4.5±0.53 ^{ab}
	100	4.8±0.22 ^a	4.9±0.12 ^a	4.8±0.42 ^a	4.6±0.27 ^a	4.6±0.52 ^a
CD at 5%	0.28	0.18	0.16	0.20	0.24	
Instant kheer mix	0	4.9±0.10 ^a	4.9±0.10 ^a	4.9±0.13 ^a	4.8±0.16 ^a	4.8±0.26 ^a
	50	4.8±0.28 ^a	4.6±0.31 ^b	4.8±0.19 ^a	4.8±0.25 ^a	4.7±0.67 ^a
	75	4.8±0.23 ^a	4.6±0.24 ^b	4.8±0.19 ^a	4.8±0.20 ^a	4.7±0.59 ^a
	100	4.9±0.12 ^a	4.9±0.10 ^a	5.0±0.00 ^a	4.8±0.19 ^a	4.8±0.49 ^a
CD at 5%	0.31	0.27	0.30	0.23	0.26	
Instant upma mix	0	5.0±0.00 ^a	4.8±0.53 ^a	4.7±0.42 ^a	4.5±0.53 ^a	4.7±0.48 ^a
	50	4.5±0.47 ^b	4.4±0.53 ^{bc}	4.6±0.46 ^a	4.5±0.47 ^a	4.5±0.53 ^{ab}
	75	4.5±0.47 ^b	4.4±0.47 ^{bc}	4.6±0.52 ^a	4.5±0.47 ^a	4.5±0.47 ^{ab}
	100	4.5±0.47 ^b	4.5±0.46 ^b	4.7±0.48 ^a	4.5±0.53 ^a	4.6±0.52 ^a
CD at 5%	0.30	0.24	0.29	0.21	0.18	
Noodles	0	4.7±0.38 ^a	4.7±0.31 ^a	4.8±0.24 ^a	4.8±0.20 ^a	4.8±0.27 ^a
	50	4.6±0.44 ^a	4.7±0.23 ^a	4.6±0.46 ^a	4.8±0.25 ^a	4.6±0.55 ^{ab}
	75	4.6±0.40 ^a	4.7±0.29 ^a	4.6±0.42 ^a	4.8±0.25 ^a	4.7±0.51 ^a
	100	4.6±0.52 ^a	4.5±0.32 ^b	4.4±0.45 ^b	4.5±0.25 ^a	4.4±0.60 ^c
CD at 5%	0.32	0.17	0.28	0.34	0.15	
Extruded snack product	0	4.8±0.33 ^a	4.8±0.26 ^a	4.9±0.21 ^a	4.9±0.16 ^a	4.9±0.21 ^a
	50	4.6±0.70 ^b	4.8±0.35 ^a	4.4±0.52 ^b	4.9±0.21 ^a	4.7±0.48 ^b
	75	4.6±0.70 ^{bc}	4.6±0.46 ^b	4.4±0.46 ^{bc}	4.9±0.21 ^a	4.5±0.47 ^c
	100	4.8±0.69 ^a	4.8±0.33 ^a	4.9±0.46 ^a	4.9±0.21 ^a	4.9±0.35 ^a
CD at 5%	0.23	0.17	0.36	0.24	0.18	

Values with different superscripts in a column differ significantly ($p<0.05$), ($n=10$ panelists)

Max. sensory scores: 5-excellent, 4-very good, 3-good, 2-fair, 1-poor. * popular low grade rice varieties

expansion is reported to be dependent on the formation of a starch matrix that entraps the water vapor, resulting in formation of bubble (Anestare Hagenimana et al. (2006). In the present study, lower expansion in PLR extruded product might be attributed to the greater fragmentation of starch and were

reported to depend upon moisture content acting as plasticizer during extrusion cooking reduces the degradation of starch granules and this result in an increased capacity of water absorption (Anastase Hagenimana et al. 2006; Badrie and Mellows 1991).

Table 3 Quality parameters in PLR products

	Noodles	Control Product	PLR product	CD at 5%
Water absorption (%)		310.0±1.16	287.0±0.95 ^{NS}	1.93
Total solid losses (%)		5.74±0.46	6.35±0.34 ^a	1.51
Volume after cooking (ml/100 g)		340.0±1.34	312.0±0.40 ^{NS}	0.42
Cooked weight after cooking time (g/g)		4.0±0.08	3.2±0.06 ^a	1.38
Kheer				
Total Solids (%)		40.2±0.73	42.0±0.88 ^{NS}	0.72
Suspended Solids (%)		5.6±0.10	6.0±0.07 ^{NS}	0.37
Palathalikalu				
Total Solids (%)		48.6±0.59	48.8±0.62 ^{NS}	0.88
Suspended Solids (%)		7.0±0.21	7.6±0.22 ^{NS}	0.59
Extruded snack product				
Length (mm)		27.3±0.03	27.2±0.07 ^{NS}	0.01
Diameter (mm)		8.3±0.08	8.2±0.087 ^{NS}	0.01
Weight (g)		1.6±0.02	1.6±0.04 ^{NS}	0.03
Volume Expansion ratio		2.5±0.03	2.0±0.02 ^{NS}	0.08
Water Absorption Index		3.0±0.06	3.0±0.05 ^{NS}	0.01

^aSignificant difference from control at 5% level, ($n=3$).

NS Non Significant

As compared to control recipes, PLR butter *coated balls*, *instant palathalikalu*, instant kheer mix and extruded snack product showed NS difference for protein, fat, total ash, crude fiber and carbohydrates (Table 4). Whereas, significantly higher ($p<0.05$) values for protein, fat, fiber and ash in control burfi, nutritious bar, instant upma mix and noodles than PLR products may be because of the reason that the use of legume (besan), cereal (wheat) (Oats and maize flakes) which in general contain higher amounts of protein, fat and minerals

(Gopalan et al. 2004). For the preparation of control *butter coated balls*, *instant palathalikalu*, instant kheer mix and extruded snack product, check variety (BPT 5204) was used as major ingredient. Due to this much variation were not observed between control and PLR incorporated products.

Consumer acceptability studies Consumer perceptions and acceptance of a product are critical elements in defining quality. Almost all the products received maximum scores (Like

Table 4 Nutrient profile of popular low grade rice (PLR) value added products

Products		Moisture (%)	Protein (%)	Fat (%)	Total ash (%)	Crude fiber (%)	CHO (%)	Energy (kcal/100 g)
Burfi	Control	3.9±0.24	20.6±0.75	42.3±0.67	1.0±0.02	0.46±0.02	31.6±0.96	589.7±2.53
	PLR	4.6±0.33*	10.7±0.42*	40.5±0.59*	0.13±0.0*	0.24±0.04	43.8±0.54*	582.5±2.41
Butter coated balls	Control	4.8±0.21	8.5±0.31	21.0±0.32	0.26±0.04	0.31±0.02	69.1±0.66	502.3±1.86
	PLR	3.2±0.16*	8.6±0.21	20.6±0.28	0.88±0.07	0.33±0.01	66.5±0.74	485.8±1.68
Nutritious Bar	Control	7.6±0.34	13.2±0.32	14.9±0.12	1.0±0.02	1.8±0.06	57.5±0.34	418.1±1.42
	PLR	8.2±0.56*	8.7±0.11*	13.0±0.17*	1.0±0.06	1.5±0.04*	69.1±0.41*	428.4±1.53
Instant Upma mix	Control	9.4±0.62	10.2±0.14	9.8±0.05	0.25±0.04	0.62±0.02	69.8±0.32	408.2±1.30
	PLR	9.3±0.43*	8.2±0.12*	9.1±0.06	0.84±0.04*	0.67±0.02	72.0±0.96	402.7±1.44
Instant Palathalikalu	Control	9.5±0.39	9.6±0.37	7.7±0.03	1.2±0.09	0.34±0.00	71.7±1.02	402.9±1.38
	PLRV	7.3±0.23*	9.4±0.40	7.3±0.06	1.1±0.05	0.16±0.00	68.4±0.65	402.6±2.00
Instant Kheer mix	Control	5.9±0.31	15.4±0.21	7.7±0.12	1.0±0.07	0.52±0.01	70.2±0.42	411.9±1.47
	PLR	4.2±0.10*	14.4±0.32	7.0±0.14	0.91±0.02	0.73±0.00	72.9±0.61	412.3±1.36
Noodles	Control	8.3±0.42	11.7±0.07	8.9±0.09	0.64±0.06	0.33±0.00	70.2±0.53	407.7±1.77
	PLR	7.1±0.32*	9.0±0.05*	8.2±0.07	0.73±0.05	0.37±0.00	69.9±0.44	408.4±1.91
Extruded Snacks	Control	2.9±0.04	17.0±0.12	0.46±0.02	1.6±0.04	0.45±0.01	77.7±0.42	386.6±1.47
	PLR	2.2±0.06*	17.8±0.14	0.47±0.03	1.5±0.06	0.39±0.02*	76.6±0.47	395.0±1.37

*- Significant at 5% level ($P<0.05$), ($n=3$)

extremely) by the house wives. PLR *Instant palathalikalu* (95%) were highly liked followed by instant kheer mix (92%) and extruded product (88%) than respective controls. Rests of the products were rated on par with control products. None of the products obtained lower scores i.e. dislike extremely dislike slightly, neither like nor dislike.

Storage studies Instant kheer mix and *butter coated balls* (control and PLR) recorded a gradual but significant ($P<0.05$) decrease in moisture content during 30–90 days (Table 5) while the rest of the products showed significant increase though there was no detectable off odors. There are no definite and generalized cutoff values for any of these parameters corresponding with acceptance or rejection of a product. They said to vary with the product and packaging film used. The product does not contain high amount of fat and the rate of oxidation is lowest. On these considerations kheer mix can be said to possess good chemical stability during the observed storage period. reported that a dry mix of gasa-gasa payasam was found to be stable for over 6 months when stored in polyethylene pouches at ambient temperature.

There was noted significant ($P<0.05$) decrease in moisture content of both control and PLRV *butter coated balls* during 30–90 days (Table 5). For rest of PLRV products, the moisture content increased as the storage period progressed. The increase in moisture content could be attributed to vapor transmission characteristics of the packaging material (MPP & PEP) used in the present study.

Free Fatty Acids increased gradually as the storage period progressed (Table 5) which is an indication of the extent of hydrolysis of lipids. However, the changes in FFA were not

related with changes in sensory scores for the PLR products which remained acceptable at the end of 3 months. The increase in Free Fatty Acid could be due to increased moisture content, which promoted fat oxidation during storage, thereby increasing the fat acidity.

Microbiological quality In the products (*instant palathalikalu* and *upma mix*) the total viable bacterial count showed no significant difference during 0–30 days however significant ($p<0.05$) increase on 60–90 days of storage was observed (Table 6). The decrease in bacterial count up to 60 days of storage may be due to the lower water activity and initial adaption of microorganisms to the new food media. The increase in total bacterial count after 60 days might be due to increase in water activity as well as the growth of microorganisms after adjusting with food medium (Frazier and Westhoff 1988).

Sensory quality: overall acceptability scores all the products showed significant difference ($p<0.05$) from initial to 90 days (Table 6). However, all the products were acceptable at the end of the 3 month storage period.

Conclusion

The study is highly important in the present day context of rice farmers facing problems of marketing PLRVs which are not preferred for consumption as staple rice due to their poor grain quality characteristics. The present study signifies the feasibility of utilizing PLRVs in various ready to eat and convenience products of traditional/commercial importance.

Table 5 Changes in chemical quality of PLR products during storage at 28 ± 2 °C

Product	T	Changes in moisture (%) during storage period (P)				CD	Changes in FFA (% as oleic) content during storage period (P)				CD
		0	30	60	90		0	30	60	90	
Burfi	Control	3.90±0.01 ^a	4.20±0.00 ^b	2.50±0.01 ^c	3.20±0.00 ^d	0.0172	0.80±0.13 ^a	1.56±0.15 ^b	2.53±0.13 ^c	2.73±0.10 ^d	0.0162
	PLR	4.60±0.01 ^a	4.92±0.0 ^b	3.26±0.00 ^c	3.95±0.00 ^d		0.29±0.12 ^a	0.32±0.13 ^b	0.40±0.13 ^c	0.40±0.11 ^d	
Butter coated balls	Control	4.80±0.01 ^a	5.30±0.00 ^b	5.10±0.01 ^c	4.00±0.00 ^d	0.0172	0.68±0.02 ^a	1.37±0.00 ^b	2.48±0.03 ^c	2.48±0.00 ^d	0.0147
	PLR	3.20±0.03 ^a	4.20±0.01 ^b	4.20±0.01 ^{bc}	4.00±0.00 ^d		0.76±0.02 ^a	1.38±0.02 ^b	2.74±0.05 ^c	2.74±0.00 ^d	
Nutritious bar	Control	4.22±0.02 ^a	4.38±0.01 ^b	7.60±0.01 ^c	8.22±0.05 ^d	0.0173	0.42±0.07 ^a	0.95±0.03 ^b	0.96±0.04 ^c	0.96±0.04 ^d	0.0143
	PLR	4.51±0.03 ^a	4.67±0.01 ^b	8.20±0.02 ^c	9.46±0.03 ^d		0.45±0.02 ^a	0.88±0.06 ^b	0.90±0.02 ^c	0.90±0.04 ^d	
Instant palathalikalu	Control	7.70±0.00 ^a	7.76±0.01 ^b	8.40±0.00 ^c	9.68±0.02 ^d	0.0177	0.26±0.00 ^a	0.34±0.00 ^b	0.39±0.00 ^c	0.39±0.03 ^d	0.0228
	PLR	7.40±0.00 ^a	7.39±0.00 ^b	9.30±0.01 ^c	9.57±0.00 ^d		0.32±0.00 ^a	0.36±0.00 ^b	0.54±0.01 ^c	0.54±0.02 ^d	
Instant kheer mix	Control	9.50±0.00 ^a	9.62±0.04 ^b	9.00±0.04 ^c	8.60±0.02 ^d	0.0175	0.12±0.08 ^a	0.16±0.03 ^b	0.21±0.04 ^{bc}	0.21±0.04 ^{cd}	0.0210
	PLR	7.30±0.03 ^a	7.80±0.02 ^b	7.20±0.04 ^c	7.00±0.02 ^d		0.16±0.06 ^a	0.23±0.05 ^b	0.26±0.03 ^{bc}	0.26±0.04 ^{cd}	
Instant upma mix	Control	5.90±0.05 ^a	6.49±0.02 ^b	7.67±0.00 ^c	8.81±0.01 ^d	0.0186	0.25±0.02 ^a	0.29±0.03 ^b	0.34±0.03 ^c	0.39±0.02 ^d	0.0248
	PLR	4.20±0.00 ^a	5.17±0.01 ^b	6.32±0.04 ^c	7.48±0.03 ^d		0.35±0.06 ^a	0.38±0.03 ^b	0.41±0.01 ^c	0.50±0.05 ^d	
Noodles	Control	8.30±0.02 ^a	8.69±0.05 ^b	8.82±0.04 ^c	9.17±0.01 ^d	0.0172	0.20±0.06 ^a	0.29±0.04 ^b	0.37±0.09 ^c	0.37±0.05 ^d	0.0153
	PLR	7.10±0.03 ^a	7.58±0.01 ^b	7.84±0.02 ^c	8.53±0.02 ^d		0.15±0.04 ^a	0.21±0.04 ^b	0.31±0.03 ^c	0.31±0.04 ^d	
Extruded snack product	Control	2.90±0.00 ^a	3.17±0.04 ^b	3.75±0.03 ^c	4.79±0.00 ^d	0.0151	Nil	Nil	Nil	Nil	
	PLR	2.20±0.00 ^a	2.99±0.05 ^b	3.34±0.03 ^c	4.41±0.03 ^d		Nil	Nil	Nil	Nil	

Means with different superscripts differ significantly at $P<0.05$ in a row ($n=3$)

FFA Free fatty acids

Means with different superscripts differ significantly at $P<0.05$ in a row ($n=3$)

Table 6 Changes in microbiological and sensory quality of popular low grade rice (PLR) products during storage at 28±2 °C

Product	T	PLR level,%	Changes in TVBC (log cfu/g) during storage period (P)				CD	Changes in Overall acceptability scores during storage period (P)				CD
			0	30	60	90		0	30	60	90	
Burfi	Control	0	12.2±0.30 ^a	27.2±0.20 ^b	44.5±0.20 ^c	76.1±0.30 ^d	5.631	4.8±0.24 ^a	4.7±0.48 ^a	4.6±0.57 ^a	4.3±0.51 ^{ab}	0.4677
	PLR	75	16.5±0.25 ^a	34.0±0.10 ^b	45.0±0.50 ^c	79.3±0.30 ^d		4.7±0.49 ^a	4.5±0.53 ^a	4.3±0.21 ^a	4.1±0.31 ^{ab}	
Butter coated balls	Control	0	25.1±0.15 ^a	42.0±0.40 ^b	63.3±0.30 ^c	63.2±0.40 ^c	5.3231	4.6±0.52 ^a	4.6±0.46 ^a	4.5±0.53 ^a	4.4±0.46 ^a	0.3226
	PLR	100	27.2±0.40 ^a	45.2±0.20 ^b	69.1±0.20 ^c	76.3±0.30 ^d		4.6±0.52 ^a	4.6±0.48 ^a	4.5±0.48 ^a	4.3±0.32 ^a	
Nutritious bar	Control	0	15.0±0.30 ^a	23.1±0.30 ^b	28.2±0.40 ^c	31.4±0.10 ^d	4.313	4.5±0.53 ^a	4.5±0.46 ^a	4.4±0.37 ^a	4.2±0.41 ^{ab}	0.3056
	PLR	75	17.3±0.10 ^a	26.5±0.30 ^b	32.3±0.30 ^c	37.4±0.20 ^d		4.2±0.35 ^a	4.2±0.43 ^a	4.1±0.39 ^a	3.9±0.55 ^{ab}	
Instant palathalikalu	Control	0	11.2±0.25 ^a	12.2±0.40 ^a	17.2±0.40 ^b	20.3±0.40 ^c	1.9214	4.6±0.52 ^a	4.6±0.49 ^a	4.5±0.53 ^a	4.3±0.52 ^{ab}	0.3002
	PLR	100	15.5±0.40 ^a	16.2±0.20 ^a	19.2±0.20 ^b	23.0±0.50 ^c		4.6±0.52 ^a	4.5±0.53 ^a	4.3±0.51 ^{ab}	4.3±0.48 ^{ab}	
Instant kheer mix	Control	0	8.1±0.20 ^a	11.3±0.50 ^b	14.1±0.10 ^c	17.5±0.20 ^d	1.8914	4.8±0.26 ^a	4.6±0.52 ^a	4.5±0.47 ^a	4.5±0.63 ^a	0.4230
	PLR	75	6.0±0.30 ^a	9.0±0.10 ^b	15.5±0.20 ^c	18.2±0.40 ^d		4.8±0.49 ^a	4.5±0.47 ^a	4.5±0.48 ^a	4.5±0.32 ^a	
Instant upma mix	Control	0	16.3±0.40 ^a	17.4±0.40 ^a	21.0±0.50 ^b	24.4±0.40 ^c	3.325	4.7±0.48 ^a	4.7±0.48 ^a	4.6±0.52 ^a	4.5±0.53 ^a	0.4543
	PLR	100	13.2±0.40 ^a	14.2±0.20 ^a	19.3±0.30 ^b	24.3±0.10 ^c		4.6±0.52 ^a	4.5±0.53 ^a	4.3±0.48 ^a	4.1±0.32 ^{ab}	
Noodles	Control	0	3.4±0.10 ^a	4.0±0.20 ^a	9.5±0.20 ^b	4.4±0.20 ^a	2.1374	4.8±0.27 ^a	4.6±0.57 ^a	4.6±0.48 ^a	4.5±0.35 ^a	0.4034
	PLR	75	4.3±0.20 ^a	5.3±0.40 ^a	9.0±0.30 ^b	4.2±0.10 ^a		4.7±0.51 ^a	4.5±0.57 ^a	4.4±0.46 ^a	3.9±0.59 ^b	
Extruded snack product	Control	0	ND	ND	ND	ND	ND	4.9±0.21 ^a	4.7±0.30 ^a	4.6±0.62 ^a	4.5±0.47 ^a	0.4230
	PLR	100	ND	ND	ND	ND		4.9±0.35 ^a	4.6±0.37 ^a	4.5±0.43 ^a	4.5±0.38 ^a	

TVBC Total viable bacterial count, ND Not detected

Means with different superscripts differ significantly at $P<0.05$ in a row ($n=3$)Values with different superscripts in a row differ significantly ($P<0.05$), ($n=10$ panelists)

Max. sensory scores: 5-excellent, 4-very good, 3-good, 2-fair, 1-poor

Popularization of the products and training rural entrepreneurs in preparation of these products will go a long way in creating job opportunities in rural areas and also sustainability of the PLRVs in the market.

References

- Acharya NG, Rannga Agricultural University (2004) A report of 40 Glorious years (1964–2004), ANGRAU Publication, Rajendra nagar, Hyderabad, 41–47
- Amerine MA, Pangborn RM, Roseller EB (1965) Principles of sensory evaluation of food. Academic Press, New York and London
- Anon (2007) Rice products value added, Kerala calling http://www.kerala.gov.in/keralacal_oct07/pg18-19.pdf accessed on 15.4.2009
- AOAC (1990) Official methods of analysis, 15th edn. Association of Official Analytical Chemists, Washington
- Ashwini S, Madhu SG, Prakash J (2008) Nutritional composition and *In vitro* starch and Protein digestibility of rice flakes of different thickness. The Indian Journal of Nutrition and Dietetics 44:216–225
- Badrie N, Mellows WA (1991) Effects of extrusion variables on cassava extrudates. J Food Sci 56:1334–1337
- Bhashyam MK, Hirannaiah BV, Meera MS, Aswathanarayana KN, Ali SZ (2006) Fair average quality (FAQ) analysis of paddy and rice: A relook. Journal of Food Science and Technology 43(2):213–218
- Bhattacharya KR, Sowbhagya CM, Indudhara Swamy M (1980) Quality of Indian rice. Journal of Food Science and Technology 17:189–193
- BIS (1976) IS: 1485, Specification for macaroni, spaghetti and vermicelli. Bureau of Indian Standards, New Delhi
- Chitra M, Singh V, Ali SZ (2010) Effect of processing paddy on digestability of rice starch by *in vitro* studies. J Food Sci Technol 47(4):414–419
- Cruick SR, Dugid JP, Marnion BP, Swain RHA (1975) The practice of medicinal microbiology. Medicinal Microbiology, Churchill Livingstone, London, 66(2):1–9
- Directorate of Economics and Statistics (2008) Hyderabad, Andhra Pradesh
- Directorate of Rice Research, DRR, (2004). Laboratory Manual on Rice Grain Quality Procedure, Directorate of Rice Research, Rajendranagar, Hyderabad
- Frazier WC, Westhoff DC (1988) Principles of food preservation. Indian Food Microbiology, 4th ed. Mc Graw Hill, 81–118
- Gopalan C, Rama Sastri BV, Balasubramanian SC (2004) Food composition tables. In: Nutritive value of Indian foods, (revised and updated by Narasinga Rao B S, Deosthale Y G and Pant KC) National Institute of Nutrition, Indian Council of Medical Research, Hyderabad
- Govindaswamy S, Ghosh AK (1969) Time of harvest, moisture content and method of drying on milling quality of rice. Oryza 6:54–66
- Hagenimana A, Ding X, Fang T (2006) Evaluation of rice flour modified by extrusion cooking. J Cereal Sci 43:38–46
- ISI (1974) IS: 3137, Specification for high-protein mixes for use as food supplements. Bureau of Indian Standards, New Delhi
- ISI (1981) Handbook of food analysis. Dairy products – Part XI. Bureau of Indian Standards, New Delhi
- Juliano BO (1990) Rice grain quality: problems and challenges. Cereal Foods World 35:245–253
- Larmond E (1977) Laboratory methods for sensory evaluation of foods, Canada Department of Agriculture Publication, Ottawa, 1637
- Matz SZ (1991) Pasta Technology. In: The Chemistry and Technology of Cereals as Food and Feed. 2nd edn. Van Nostrand Reinhold, New York, pp 451–496
- Mercier C, Feillet P (1975) Modification of carbohydrate component by extrusion cooking of cereal product. Cereal Chem 52:283
- Meullenet JFC, Gross J, Marks BP, Daniels M (1998) Sensory descriptive texture analysis of cooked rice and its correlation to instrumental parameters using an extrusion cell. Cereal Chem 75:714–720
- Ong MH, Blanshard JMV (1995) Texture determinants in cooked parboiled rice. I: Rice starch amylase and the fine structure of amylopectin. Journal of Cereal Science 21:261–269
- Priyadarsini J, Prasad PVN (2003) Grain quality of rice as affected by varieties and nitrogen source Andhra. Agric J 50(1 & 2):14–17
- Ramesh M, Ali SZ, Bhattacharya KR (1999) Structure of rice starch and its relation to cooked-rice texture. Carbohydrate Polym 38:33–347
- Shobha Rani N, Madhav S, Pandey MK, Sundaram RM, Prasad GSV, Sudharshan I, Subba Rao LV, Ravindrababu V (2008) Genetics and molecular approaches for improvement of grain quality traits in rice. Indian J crop Sci 3(1):1–14
- Snedecor GW, Cochran WG (1989) Statistical methods. Iowa State University Press, Ames
- Sowbhagya CM, Zakiruddin Ali S (2001) Vermicelli noodles and their quality assessment. J Food Sci Technol 38(5):423–432
- Sudha ML, Vetrmani R, Rahim A (1998) Quality of vermicelli from finger millet (*Eleusine Coracana*) and its blend with different millet wheat fraction. Food Res Intern 31:99–104
- Toriyama K, Heong KL, Hardy B (2005) Rice is life: Scientific perspectives for the 21st century, Proceedings of the world Rice Research Conference held in Tokyo and Tsukuba, Japan, 4–7 November 2004
- Zhou Z, Robards K, Helliwell S, Blanchard C (2002) Ageing of stored rice: changes in chemical and physical attributes. Journal of Cereal Science 35:65–78