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# Effect of storage on resistant starch content of processed ready-to-eat foods

J. Namratha[a], Urooj Asna[a,*], N.N. Prasad[b]

[a]Department of Studies in Food Science and Nutrition, University of Mysore, Mysore-570006, India
[b]Defence Food Research Laboratory, Siddartha Nagar, Mysore-57001, India

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**Abstract**

In recent years, there has been an increased demand for processed convenient foods, particularly for the Armed Forces. Such foods should provide energy and other nutrients in the required proportions to promote health and nutrition of the army personnel. This study evaluated the effect of storage on the resistant starch (RS) content of selected ready-to-eat (RTE) foods, viz., vegetable kichidi, vegetable pulav, chicken pulav, mutton pulav, sooji halwa, upma, cauliflower peas curry and potato peas curry prepared by Defence Food Research Laboratory (DFRL). Resistant starch was quantified directly in the residues obtained after removing digested starch in simulated physiological conditions. Nutrient content and carbohydrate profile of the foods were also analysed. Nutrient content varied depending on the basic ingredients used in their preparation. Total starch ranged from 18–74% and dietary fibre 13–20%, respectively. Storage of 4 months resulted in a significant increase ($P<0.05$) in the RS content of all foods except mutton pulav. It appeared that in addition to processing methods used, duration of storage could be an important factor, affecting RS formation in RTE foods.



*Keywords:* Processed foods; Storage; Resistant starch

## 1. Introduction

Quantitatively, starch is the most important carbohydrate in the human diet. It represents the primary energy source, contributing to nearly 60–70% of the total energy consumed, of which nearly 75% of the starch is derived from cereals, and pulses (Asp, 1995; National Nutrition Monitoring Bureau, 1991). It is a glucose polymer of two distinct structural forms, amylose and amylopectin (Tharanathan, 1995).

During processing, the starch molecule undergoes several physical modifications depending on the type of contained starch and severity of the conditions employed (Goni, Garcia-Diz, Manas, & Saura Calixto, 1996), leading to the formation of resistant starch (RS) that escapes digestion and absorption in the intestine (Annison & Topping, 1994), and later, is fermented by the gut microflora (Berry, 1986). The latter phenomena is of greater significance nutritionally, as it is implicated in the preventive mechanisms against several intestinal disorders (Annison & Topping, 1994; Gee, Johnson, & Lind, 1992).

The rate and extent of starch digestion and absorption is reported to be influenced by a variety of factors both intrinsic and extrinsic (Englyst & Hudson, 1996; Jenkins, Jenkins, Wolever, Thompson, & Rao, 1986). The digestibility characteristics of starch-based foods, mostly depends on the processing conditions adopted and the resulting retrogradation steps (Siljestrom, Eliason, & Bjorck, 1989).

Chemically, RS results from the highly retrograded amylose fraction, the quantity formed being directly proportional to the linear amylose content of starch (Annison & Topping, 1994). Thus, the degree of formation of RS in foods, depends on the type of contained starch, processing condition adopted, and is also influenced by the duration and storage conditions (Goldblith, 1971; Goni et al., 1996).

The studies reported in the literature on the RS content and the related changes induced during various

* Corresponding author. Tel.: +91-821-495789; fax: +91-821-518835.

*E-mail address:* asna321@e-mail.com (U. Asna).

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cooking processes and subsequent storage have employed a range of products viz., bread, breakfast cereals, biscuits, boiled rice and potato, parota and wheat flour, oats, banana, (Asp, 1995; Englyst & Hudson, 1996; Englyst, Kingman, & Cummings, 1992; Goni et al., 1996; Siljestrom et al., 1989; Muir & O'Dea, 1992). Results of these studies indicate that different processing techniques/conditions adopted exert varied effects on the content of RS formed.

Defence Food Research Laboratory, Mysore, India, one of the pioneering food research institute of the country has developed several processed traditional Indian foods either in ready-to-eat (RTE) or easy-to-reconstitute (ETR) forms for use of the Armed Forces deployed under stringent atmospheric and climatic conditions. These foods established to be microbiologically safe and organoleptically acceptable even at the end of 6–12 months storage at ambient conditions, have been extensively studied for their nutrient composition, protein quality and changes in dietary fibre content (Prasad, Khanum, Swamy, & Santhanam, 1995; Prasad, Vishwanatha, & Santhanam, 1991). Limited information is available in the literature on the RS content of traditional Indian foods and their relative nutritional significance (Kavitha, Verghese, Chitra, & Prakash, 1998). Recent studies have reported the RS content of wheat-based Indian foods (Tharanathan & Tharanathan, 2001) and the nutritionally important starch fractions including RS in cereal-based Indian foods (Sharavathy, Urooj, & Puttaraj, 2001).

In view of the above and since the RTE and ETR products developed by DFRL, Mysore are exposed to several processing treatments like blanching, frying, cooking, in-pack sterilisation, etc., the present study aims to evaluate the effect of storage on the RS content in selected RTE foods.

## 2. Materials and methods

The various processed foods used in the study were obtained from the Food Engineering and Packaging Discipline of the laboratory. The raw materials used and the processes employed in their preparation are given in Tables 1 and 2. The references cited against each of the products indicate the processing techniques adopted and their method of reconstitution/use. Some of the processes are also described here.

### *2.1. Preparation of mutton/chicken pulav*

De-boned and dressed meat was cut into chunks (1–11/2 inches) washed and drained of excess water. The chunks were fried in hydrogenated oil, and kept aside. Cleaned and washed rice was fried in oil in a shallow stainless steel pan. The powdered spice mix (Garam masala) was added, mixed and set aside. Finely chopped onions were fried, a paste of ginger, garlic and green chillies was added together with a calculated quantity of water. Previously fried rice and meat was added, mixed and allowed to cook till done, and packed in retort pouches.

Table 1
List of ingredients used in the preparation of various products and their botanical names

| S.No. | Ingredients used | Botanical names |
|---|---|---|
| 1. | Wheat | *Triticum aestivum* |
| 2. | Rice | *Oriza sativa* |
| 3. | Bengal gram | *Cicer arietinum* |
| 4. | Peas | *Pisuin Sativum* |
| 5. | Peanut | *Arochis hypogaee* |
| 6. | Potatoes | *Solanum tuberosum* |
| 7. | Onion | *Allium Cepa* |
| 8. | Ginger | *Zingiber efficinale* |
| 9. | French Beans | *Phaseolus concemum* |
| 10. | Lemon | *Citrus limon* |
| 11. | Tomato | *Lycopersicon esculentum* |
| 12. | Garlic | *Allium salivum* |
| 13. | Cumin Jeera | *Cummum cyminum* |
| 14. | Pepper | *Piper nigrum* |
| 15. | Turmeric | *Curcuma domestica* |
| 16. | Cinnamon | *Cinnamomum Zeylanicum* |
| 17. | Cloves | *Syzgium aromaticum* |
| 18. | Cardamom | *Elettaria Cardamomum* |
| 19. | Curry Leaves | *Murraya Koenigin* |
| 20. | Chiranji | |
| 21. | Carrot | *Daucus carota* |
| 22. | Green gram/Moong | *Phaselous aureus Rox*b |

### *2.2. Vegetable khichdi*

Split green gram, sliced onion and rice (washed and drained) were fried in hydrogenated fat The spices, salt, sliced potato, peas and water were added, mixed well and cooked till done. It was packed in flexible pouches. Both vegetable kichidi and mutton/chicken pulav were inpack sterilised as described earlier (Srivatsa et al., 1993).

#### *2.2.1. Analytical methods*

The samples for analysis were drawn from a minimum of 3 batches of each of the prepared products. The products were stored in an insect proof chamber at ambient conditions prevailing in Mysore (India). At the end of the storage period (4 months), the samples were drawn and analysed for resistant starch.

(i) Proximate composition: all the products were analysed in triplicate for their proximate composition by the AOAC methods (AOAC, 1984).

(ii) Free sugars: reducing and total sugar contents were estimated titrimetrically according to Shaffer–Somogyi micro method (AOAC, 1984).

Table 2
List of various RTE products, their major ingredients and methods of processing

| Item | Ingredients | Processing |
|---|---|---|
| 1. Sooji halwa (sweet semolina pudding) | Wheat semolina (Bansi variety)—5 kg; cane sugar—10 kg; hydrogenated oil—3 kg; chironji—0.15 kg; cardamom (whole)—0.07 kg | Ghosh, Krishnappa, Srivatsa, Eapen, and Vijayaraghavan, 1980 Krishnappa, Srivatsa, Ghosh, Eapen, and Vijayaraghavan, 1982 |
| 2. Potato peas curry | Dry peas—1 kg; hydrogenated oil —2 kg; potato —4 kg; garlic (whole)—100 g; ginger (fresh)—100 g; tomato (Madanapalli variety)—1.5 kg; onion (fresh)—1.5 kg; chili powder —50 g; turmeric powder—50 g; cumin powder—25 g; white pepper powder—25g; salt—150 g | Ghosh et al., 1980 Krishnappa et al., 1982 |
| 3. Cauliflower curry | Dry peas—1 kg; hydrogenated oil —2 kg; cauliflower (dressed) 4 kg; garlic (whole)—100 g; Ginger (fresh)—100 g; tomato—1.5 kg; onion (fresh)—1.5 kg; chilli powder—50 g; turmeric powder—50 g; cumin powder—25 g; white pepper powder —25 g; salt—150 g | Ghosh et al., 1980 Krishnappa et al., 1982 |
| 4. Vegetable pulav | Rice (good quality) —3 kg; hydrogenated oil—1 kg; onion (fresh)— 1 kg; carrot dressed—2 kg; depodded green peas —2 kg; beans dressed —2 kg; garlic (whole)—75 g; ginger (fresh)—75g; cinnamon—10 g; cloves—10 g; cardamom—10g; green chillies—85 g; salt—100 g | Jayaraman et al., 1980 Srivatsa et al., 1993 In the present case the product is packed in flexible pouches and in-pack sterilised (instead of canning) as described by Ghosh et al. (1980) and Krishnappa et al. (l982). |
| 5. Upma (savory semolina pudding) | Wheat semolina 5 kg; hydrogenated peanut oil—1.5 kg; Bengal gram dhal—35 g; de-podded green peas—1 kg; green chillies—120 g; curry leaves—200 g; ginger—60 g; salt—200 g; lemon juice—800 ml; water—7 l | Prasad et al., 2000 |
| 6. Chicken pulav | Chicken—40 kg; Basmati rice 8 kg; onion—7 kg; garlic—250 g; ginger—250 g; green chilies—250 g; cinnamon and cloves—5 g each; hydrogenated fat—1 kg; refined oil—750 m1, salt—450 g; water—8 l | See Text |
| 7. Mutton pulav | Meat—30 kg; Basmati rice—7.5 kg; onion—6 kg; garlic—250 g; ginger—250 g; green chillies—250 g; cinnamon and cloves—5g each; hydrogenated fat—1 kg; refined oil—750 m1, salt—450 g; water—8l | See Text |
| 8. Vegetable kichdi | Rice—4.5 kg; potato sliced, onion—4.5 kg; split green gram—2 kg; fresh peas—6 kg;turmeric powder—10 g; refined oil & hydrogenated fat—750 g each; onion—4 kg; cardomom and cloves—5 g each, green chilies—85 g; salt—100 g; water—7 l | See Text |

(iii) Dietary fibre: defatted residues of all the samples were finely powdered using a Waring blender to pass through a sieve of 100 mesh. This fine powder of each sample was used in triplicate for the estimation of soluble (SDF), insoluble (IDF) and total dietary fibre (TDF) by the enzyinatic-gravimetric method of Asp, Johnson, Hollmer, and Siljestrom (1983).

(iv) Starch: the total starch (TS) content was analysed by the method of Englyst et al. (1992).

(v) Resistant starch: the RS content was quantified directly in fresh food samples, according to the method of Goni et al. (1996). A schematic description of the method is depicted in Fig. 1. The method essentially involves removal of protein and digestible starch, solublisation and enzymatic hydrolysis of RS. The RS content was finally measured as the amount of glucose released. The RS content was estimated in both fresh and stored samples (4 months).

### 2.2.2. *Statistical analysis*

The data obtained with respect to RS estimation in 4 replicates, were analysed as mean and standard deviation. Students '*t*' test was applied to compare RS content before and after storage (4 months).

## 3. Results

The proximate composition of the different foods is given in Table 3. As seen from the values the protein content of both chicken and mutton pulav are higher compared to the other products and is attributable to the presence of meat. The fat content ranged from 10.2–23.5 g%. These values are comparable to values reported earlier (Prasad et al., 1995). Except for upma, all the products contained higher amounts of free sugars (Table 4). The reducing sugars ranged from 2.2–17.9 g/100 g. The

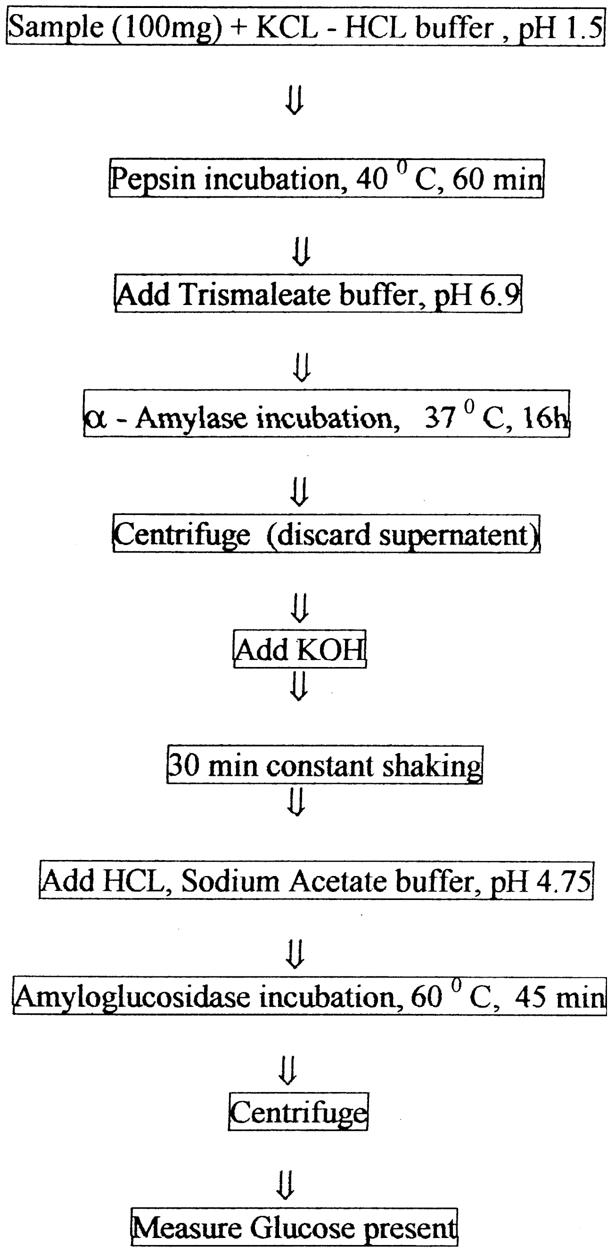


Fig. 1. Analytical procedure for estimation of resistant starch.

Table 3
Proximate composition of selected RTE foods (g/100 g dry weight)

| Foods | Moisture | Protein | Crude fat | Total ash | Carbohydrate[a] |
|---|---|---|---|---|---|
| Vegetable kichidi | 4.0 | 15.4 | 15.4 | 5.3 | 59.9 |
| Vegetable pulav | 6.0 | 14.4 | 10.8 | 6.8 | 62.0 |
| Chicken pualv | 4.0 | 23.9 | 23.5 | 4.9 | 43.7 |
| Mutton pulav | 4.0 | 28.1 | 16.8 | 6.9 | 44.2 |
| Sooji halwa | 1.0 | 4.0 | 12.6 | 0.4 | 82.0 |
| Upma | 3.0 | 14.3 | 10.2 | 5.7 | 66.8 |
| Potato peas curry | 6.0 | 17.3 | 16.5 | 2.0 | 58.2 |
| Cauliflower peas curry | 6.0 | 16.5 | 20.5 | 2.0 | 54.8 |

Mean values of triplicate analysis.
[a] By difference.

total starch content ranged from 18% in mutton pulav to 49% in sooji halwa. The starch content varied depending on the ingredients used in the preparation. The IDF and TDF content of mutton pulav and upma were higher than the values for the rest of the products. All foods had lower SDF content, the exception being Vegetable khichdi (5.9 g).

The RS content of the food products both before and after storage are given in Table 5. As seen, the RS content was lowest in cauliflower peas curry followed by mutton pulav, while higher RS values were observed in three foods viz., upma, vegetable khichdi and vegetable pulav, both before and after storage. Storage of foods under ambient conditions resulted in a significant increase in the RS content in all the products except mutton pulav.

Since, total starch (TS) is a component of total carbohydrates present in any food product, the available starch (AS) and RS are expressed as percentage of TS (Table 6). The AS content (expressed as % of TS) which ranged from 74 to 95% decreased on storage

Table 4
Carbohydrate profile of selected RTE foods (g/100 g dry weight)

| Foods | Free sugars | Total starch | Total dietary fibre (TDF) | | Total carbohydrate[a] |
|---|---|---|---|---|---|
| | | | IDF + | SDF | |
| Vegetable khichdi | 11.9 | 36.9 | 12.3 | 5.9 | 67.0 |
| Vegetable pulav | 16.4 | 39.1 | 12.3 | 1.1 | 68.4 |
| Chicken pulav | 11.1 | 21.2 | 12.2 | 1.0 | 45.4 |
| Mutton pulav | 10.1 | 18.0 | 18.8 | 1.2 | 48.1 |
| Sooji halwa | 17.9 | 49.2 | 10.3 | 2.5 | 79.9 |
| Upma | 2.2 | 43.5 | 17.2 | 1.1 | 63.9 |
| Potato peas curry | 15.6 | 24.1 | 10.1 | 3.0 | 52.9 |
| Cauliflower peas curry | 14.3 | 27.2 | 5.1 | 0.4 | 57.2 |

IDF—insoluble dietary fibre, SDF—soluble dietary fibre.
[a] Sum of analysed values.

Table 5
Resistant starch content of selected RTE foods (g/100 g fresh weight)

| Foods | Resistant starch (before storage) | Resistant starch (after storage) | '$t$' Value (6 df)[a] |
|---|---|---|---|
| Vegetable kichidi | 3.42±0.10 | 4.20±0.0 | 8.16** |
| Vegetable pulav | 2.92±0.10 | 4.08±0.10 | 8.91** |
| Chicken pulav | 1.34±0.05 | 3.45±0.13 | 15.00* |
| Mutton pulav | 0.80±0.18 | 1.00±0.08 | 1.74[NS] |
| Sooji halwa | 2.35±0.24 | 3.65±0.42 | 2.41* |
| Upma | 4.10±0.43 | 5.78±0.13 | 5.08** |
| Potato peas curry | 1.50±0.14 | 1.92±0.13 | 2.48* |
| Cauliflower peas curry | 0.22±0.02 | 0.35±0.00 | 5.50* |

Mean+S.D. of foods before and after storage and their difference. Minimum of 4 replicates. NS, Not significant.
[a] d.f.—Degree of freedom.
* $P<0.05$.
** $P<0.01$.

Table 6
Comparison of starch fractions[a] as% of total starch (before and after storage)

| Foods | Total starch (TS) | As % of total starch | | | |
|---|---|---|---|---|---|
| | | Before storage | | After storage | |
| | | AS | RS | AS | RS |
| Vegetable kichidi | 36.9 | 77.0 | 23.0 | 71.8 | 28.2 |
| Vegetable pulav | 39.1 | 74.4 | 25.6 | 63.6 | 36.3 |
| Chicken pulav | 21.2 | 85.8 | 14.2 | 63.3 | 36.9 |
| Mutton pulav | 18.1 | 90.4 | 9.6 | 88.0 | 12.2 |
| Sooji halwa | 49.2 | 92.7 | 7.3 | 88.6 | 11.4 |
| Upma | 43.5 | 81.0 | 19.0 | 73.0 | 26.9 |
| Potato peas curry | 24.1 | 78.3 | 21.7 | 72.5 | 27.4 |
| Cauliflower peas curry | 27.3 | 95.8 | 4.2 | 93.5 | 6.6 |

[a] AS—Available starch, RS—resistant starch, on moisture free basis.

with a corresponding increase in RS content expressed similarly. The RS content ranged from 4.2 to 25% before storage and from 6.6 to 37% after storage. It may be observed that the highest increase in RS was found to be in chicken pulav compared to the other products.

## 4. Discussion

The present study reports the effect of storage on the RS content of some selected RTE foods. The selected food products were stored at room temperature for a 4 month duration, in flexible pouches, which provide maximum barrier against water, oxygen and light permeability. The processed foods had a minimum shelf-life of 6 months with acceptable sensory qualities when stored at room temperature.

Recent studies have shown that many carbohydrate-rich foods contain variable amounts of RS (Annison & Topping, 1994; Orford & Johnson, 1988). Several factors determine the proportion of dietary starch that becomes RS. Important factors are starch source, granular structure of starch, degree of processing and presence of other nutrients like protein, fat and fibre (Annison & Topping, 1994; Muir & O'Dea, 1992; Siljestrom et al., 1989). In the present study, RS content varied depending on the ingredients used and type of processing. All the products had relatively high moisture content and were subjected to boiling/autoclaving. It is reported that autoclaving of starchy foods at high moisture content results in formation of retrograded starch (Siljestrom et al., 1989), which is particularly resistant to hydrolysis (Kavitha et al., 1998). The RTE foods containing the most RS were vegetable pulav, vegetable kichdi, potato peas curry and upma. The higher RS content in these foods reflects the presence of starch with the A & B type crystal structure which is resistant to enzymatic digestion (Annison & Topping, 1994). Thus, it is possible that the processing conditions, viz., boiling/autoclaving, used in the preparation of RTE foods favour the formation of retrograded starch.

In addition to processing, other potential causes of RS variability may be due to the presence of protein and fat. In foods like upma, sooji halwa, kichdi and vegetable pulav, the higher RS content may be due to the presence of both high fat and protein content. It is also reported that lipids may influence the RS formation (Siljestrom et al., 1989). Although 2 other RTE foods, mutton and chicken pulav also had higher fat and protein content, the RS content was lower than other foods. This may be attributed to a lower TS content in these foods.

All processed foods are invariably stored before consumption (Annison & Topping, 1994). During storage, the dispersed polymers of gelatinised, starch are said to undergo retrogradation to semi-crystalline forms that resist amylolitic digestion. The higher RS content in foods such as upma, sooji halwa and chicken pulav on storage may be due to starch forming molecular complexes with proteins and lipids rendering it less susceptible to enzymatic digestion (Holm et al., 1983). In general, all foods except mutton pulav showed a significant increase in RS content on storage.

The results of the present study indicate that in addition to processing and ingredients used, duration of storage is also an important factor affecting the formation of RS in RTE foods. Foods with appreciable amounts of RS may affect the digestibility of other nutrients, and thus may have important implications for the energy value of RS (Livesey, 1990). This observation suggests that high RS foods may result in significant energy losses from the small intestine. Although it is expected that some of the escaped RS reaching the large bowel may also contribute to metabolizable energy by production of short chain fatty acids (Behall & Howe, 1995; Tovar, Bjorck, & Asp, 1990). Consumption of RS containing foods appear to offer many health benefits in conditions including diabetes, obesity and bowel cancer. High RS foods may increase faecal bulking and changes in faecal pH, both effects are beneficial in conditions like constipation and may also protect against development of colon cancer (Annison & Topping, 1994; Bjorck et al., 1986; Shetty & Kurpad, 1986).

## 5. Conclusion

Since these RTE processed foods are part of the ration formulated by Defence Food Research Laboratory, especially for use by Armed Forces, further detailed investigations are essential to evaluate the long term physiological effects of RS.

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