



Nutritionally Important Starch Fractions and Sensory Acceptability of Oats Incorporated Pongal – A Traditional Indian Food

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Abstract

Oats are being promoted as health food ingredient for its functional attributes due to high β -glucan content. There is immense scope for utilization of oats, in formulation of high fiber food products that confer health benefits, however its utilization in Indian cuisine is limited. This study aimed to explore the use of oats as a functional ingredient in an Indian traditional food and study its sensory acceptability and starch digestibility profile. The product was formulated by replacing rice with oats at a level of 20% and evaluated for sensory acceptability and starch fractions of nutritional importance through controlled enzymatic digestion involving enzymes such as amyloglucosidase, invertase and pancreatin. In addition, estimation of rapidly available glucose and starch digestibility index was carried out. Sensory analysis revealed that the product was acceptable, with no noticeable differences observed between control pongal (CP) and oats integrated pongal (OP) in terms of color, appearance, texture, aroma, mouthfeel, after taste, and overall acceptability. The addition of oats led to a substantial decrease in total starch and resistant starch content, whereas rapidly digestible starch (RDS), slowly digestible starch (SDS) and rapidly available glucose (RAG) increased significantly. The starch digestibility index of OP was 31, which was significantly greater than the starch digestibility index of CP, which was 16. These findings suggest that incorporation of oats helps in value addition of pongal in terms of enhanced digestibility with increased soluble dietary fiber content that aids in healthy gut microbiome.



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Introduction

Starch derived from cereal-based food products is the main source of energy for the majority of world's population. Based on their *in vitro* digestibility pattern, these starches are categorized into three fractions: rapidly digestible starch (RDS) which is digested within 20 minutes, slowly digestible starch (SDS) which is digested between 20-120 minutes, and resistant starch (RS) which remains undigested even after 120 minutes.¹ Both SDS and RS are believed to have significant health benefits; former being hydrolyzed slowly aiding in glucose homeostasis while, the latter escapes digestion and undergoes fermentation to yield biologically important substances beneficial in reducing the risk of colonic diseases.^{2,3} "Pongal" is one such cereal-pulse based traditional preparation commonly consumed in South India having higher starch digestibility characteristics owing to the ingredients used and the method of preparation. Previous studies revealed higher SDI, RDS *in vitro*⁴ and higher GI among type 2 diabetic subjects due to higher degree of gelatinization being reflected in higher digestibility index.⁵ Because, starch digestibility depends on both intrinsic and extrinsic factors,¹ processing conditions and addition of specific food components can result in redistribution of starch fractions thereby opening the window for customized food product development for different populations.⁶

Oats are one such functional ingredient which have tremendous potential to be used in the development of functional foods. However, their usage is limited to porridges and other simple breakfast cereals.⁷ More recently, the interest in utilizing oats in food product development is on the rise not only due to the presence of high amounts of β -glucans having lipid lowering/plasma glucose stabilizing effect but also due to the unique gelatinization characteristics of its starch which behaves like a waxy starch owing to high shear susceptibility. The high viscosity starch gel thus formed is less susceptible to retrogradation upon cooling forming an elastic, adhesive and less firm gel compared to other cereal starches. It is opined that these characteristics make oats starch suitable to be used in the formulation of infant foods. Absence of gluten is an advantage for using oats as an alternative to wheat in infant formula.⁷⁻⁹ It is also interesting that, incorporating oats into food products not only increases soluble dietary fiber content (β -glucan) offering lipid lowering and plasma glucose

stabilizing effects, but also contributes to minor phytochemicals having health beneficial effects including improvement of gut health.⁷⁻¹⁰ Moreover, limited studies report nutritionally important starch fractions in food preparations⁶ and thus, modification in food formulations by replacing ingredients with oats is a practical approach to modulate the starch digestion. With the above context in sight, an attempt was made to use oats as a functional ingredient in 'pongals' and evaluate its influence on digestibility of starch with respect to different starch fractions of nutritional significance using an *in vitro* assay.

Materials and Methods

Materials

All of the food ingredients were acquired at a nearby store. Amyloglucosidase, pancreatine, invertase (Sigma-Aldrich), and glucose oxidase-peroxidase assay pack (Randox, USA) were used. All the other reagents used in the study were of laboratory grade.

Preparation of Pongal

Rice Pongal was prepared in a traditional way. Rice (50 g), split green gram/mung dal (*Vigna radiata*, 20 g), and 350 mL water were mixed and pressure cooked for 10 minutes. Sunflower oil (30 g) was heated in a cooking pan for seasoning, and to this equal amount of cumin seeds and mustard (2.5 g) were added. After spluttering of mustard and cumin seeds, green chillies (4 no), curry leaves (5 g), turmeric powder (1/2 tsp) were added and sautéed for 2-3 min on low heat. This seasoning was then added to pressure cooked rice mixture along with salt (1/2 tsp) and mixed well. Oats incorporated pongal (OP) was prepared by replacing 20% of rice with oats (10 g) based on earlier studies incorporating oats in different Indian food preparations of high GI.⁶

Sensory Analysis

Semi-trained jury of ten members familiar with the product evaluated the sensory acceptability of CP and OP in terms of color, appearance, texture, aroma, mouthfeel, after taste, and overall acceptability. Sensory analysis was done in designated rooms with air conditioner set at 20°C. The rooms were adequately lit with white LED lamps. The "Quantitative Descriptive Analysis" approach was employed, with a scale of 0-10 cm anchored at 1.0 cm on each end. The left end marked as 'Low' indicated recognition threshold, whereas the right end marked as 'High' indicated saturation

threshold. The samples were served hot in small bowls labelled with random four-digit codes. Along with the samples, drinking water and bland biscuits were served as palate cleansers.

Panelists were asked to draw a diagonal line on the scale and write the code number to represent the perceived intensity of each characteristic attribute

on the score card. Individual panelists' judgments were represented by tabulating the scores for each attribute for a given sample. Finally, an average score for each sample attribute was calculated, showing the panel's judgment on the sensory quality to assess the product's acceptability. This is depicted graphically as a "Sensory Profile".¹¹

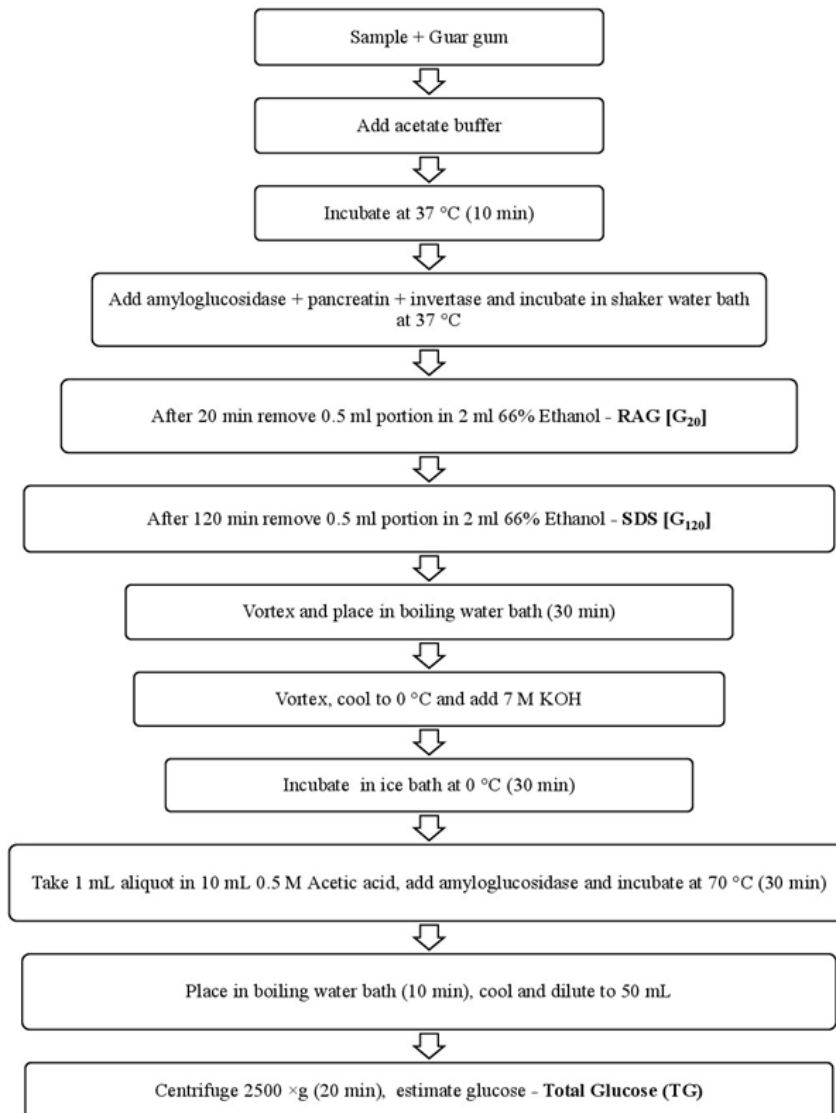


Fig.1: A graphical overview of the analytical technique for measuring starch fractions

Estimation of Starch Fractions of Nutritional Significance and Starch Digestibility Index

An *in vitro* approach was used to quantify total starch (TS) and starch fractions of nutritional importance

namely rapidly digestible starch (RDS), resistant starch (RS), slowly digestible starch (SDS) and rapidly available glucose (RAG).¹ Different starch fractions were determined in freshly prepared

food samples by incubating them with invertase, pancreatin, and amyloglucosidase at 37°C in 50 mL polypropylene-capped tubes placed in a shaker waterbath. To mimic intestinal digestive conditions, glass beads were introduced into the tubes which caused disruption of food particles and guar gum was added which brought the viscosity of the reaction mixture similar to that of gastrointestinal tract. The reaction mixture's glucose content was determined at 20 minutes (G_{20}) to estimate rapidly available glucose (RAG) and at 120 minutes (G_{120}) to estimate slowly digestible starch (SDS). The tubes were then immersed in boiling water to gelatinize the starch and then placed into an ice bath before being treated with 7M KOH to determine total starch content (TG). Resistant starch content was determined by the amount of undigested starch remained after 120 minutes of incubation and the free glucose (FG) concentration was determined by adding acetate buffer to the sample tubes and placing them for 30 minutes in a boiling water bath. A blank tube containing all reagents except sample was also used to account for glucose present in amyloglucosidase enzyme solution. A tube containing dextrose was also treated in same manner and used as reference standard. Throughout the experiments, glucose content was measured in all samples using a glucose oxidase–peroxidase enzyme assay package. Figure 1 illustrates the overview of the analytical technique used in the study.

Using the values of G_{20} (glucose liberated at 20 minutes), G_{120} (glucose liberated between 20-120 minutes), free glucose (FG) and total glucose (TG), total starch (TS), rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) were calculated. The following are the formula for the aforementioned calculations.

Total starch (TS) = $(TG - FG) \times 0.9$

Rapidly digestible starch (RDS) = $(G_{20} - FG) \times 0.9$

Slowly digestible starch (SDS) = $(G_{20} - G_{120}) \times 0.9$

Resistant starch (RS) = $TS - (RDS - SDS) \times 0.9$ or $(TG - G_{120}) \times 0.9$

Starch digestibility index (SDI) = $RDS / TS \times 100$

Rapidly available glucose (RAG) = $FG + G_{20}$

Statistical Treatment

The data on different starch fractions of nutritional importance and starch digestibility pattern were represented as means standard deviations of

triplicate determinations. Using SPSS 20.0 program, data were analyzed through ANOVA, accompanied by Tukey's post-hoc test to determine statistically significant variations at a confidence level of 95%.

Results and Discussion

Sensory Analysis

Figure 2 illustrates the sensory assessment of results. Despite the fact that the addition of oats made the pongal mildly viscous compared to the control pongal (CP), no substantial ($p < 0.05$) discrepancies were observed in terms of color, texture, taste, aroma, mouthfeel, after taste, and overall acceptability between the control pongal (CP) and the oats incorporated pongal (OP). CP had bright yellow color which was slightly masked by the incorporation of oats resulting in slightly pale-yellow colored product. However, the sensory score obtained for color did not differ significantly ($p < 0.05$). Consequently, oats incorporation resulted in marginal but statistically insignificant ($p < 0.05$) decrease in sensory scores for appearance compared to CP. It is noteworthy that incorporation of oats did not result in any off-taste/aroma/aftertaste, though the mouthfeel was slightly chewy compared to pongal. Both CP and OP obtained high scores for overall acceptability.

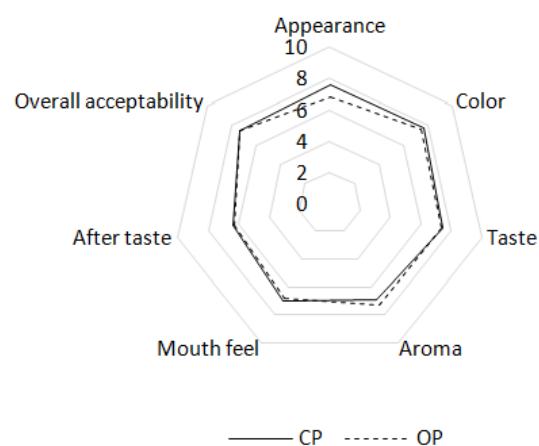


Fig.2: Sensory profile of control pongal and oats incorporated pongal

Starch Digestibility Profile

The starch digestibility characteristics of CP and OP are presented in Table 1. Results indicated substantial redistribution of starch fractions of nutritional importance leading to higher digestibility in oats incorporated pongal. The total starch (TS) and resistant starch (RS) contents of CP (control

pongal) were substantially ($p < 0.05$) higher than those of OP (oats incorporated pongal), and as a result, the rapidly digestible starch (RDS), slowly digestible starch (SDS) and rapidly available glucose (RAG) contents of OP were substantially ($p < 0.05$)

higher than those of CP. Similarly, rapidly available glucose (RAG) and starch digestibility (SDI) of OP was significantly ($p < 0.05$) higher than that of CP. It is interesting to note that despite increase in SDS, OP exhibited higher starch digestibility index than CP.

Table 1: Starch fractions of nutritional importance and starch digestibility profile of oats incorporated pongal

Characteristics	Control pongal (CP)	Oats incorporated pongal (OP)
Dry matter (%)	28	27
Total starch (TS)	21.8 ^b ± 1.32	16.8 ^a ± 0.93
Rapidly digestible starch (RDS)	3.52 ^a ± 0.35	5.27 ^b ± 0.75
Slowly digestible starch (SDS)	3.80 ^a ± 0.27	6.10 ^b ± 1.01
Resistant starch (RS)	16.95 ^b ± 1.31	5.44 ^a ± 0.98
Starch digestibility index (SDI)	15.30 ^a ± 1.40	31.46 ^b ± 1.22
Rapidly available glucose (RAG)	4.10 ^a ± 0.35	6.45 ^b ± 0.41

*Mean values in rows of distinct superscript letters a and b vary considerably ($p \leq 0.05$).

The methods used in this study affords accurate measurement of specific fractions of starch based on their susceptibility for enzymatic digestion which is influenced by food matrix.¹² The research examined the impact of incorporating oats, a reasonable source of soluble dietary fiber, on total starch, different starch fractions of nutritional importance, *in vitro* starch digestibility, and sensory acceptability of oats incorporated pongal. Despite the fact that the developed product was viscous, its acceptability was high, and the observed rise in product's viscosity can be attributed to higher β -glucan content of oats.¹³

In the present study, foods were analyzed on an 'as eaten basis' because it is important that the *in vitro* technique used correctly simulates *in vivo* starch digestion.¹⁴ Although, incorporation of oats in pongal significantly decreased total starch content, it led to significantly higher starch digestibility. The reduction in overall starch content is due to the exchange of rice starch with β -glucans found in oats, and it is also directly proportional to the content of the ingredients used in the recipe. Similar findings have been reported earlier wherein, incorporation of dietary fiber source in extruded breakfast cereal products reduced total starch content significantly.¹⁵ This observation is also in good agreement with an earlier study wherein, incorporation of oats led to a substantial reduction in the total starch content of idli, dosa, upma, and chapatti.⁶ The use of wheat and

oat bran in magwinya fried products (South African Doughnuts) has been shown to reduce RAG values while increasing SDS, indicating a delay in glucose release due to the involvement of bran fibers during enzymatic hydrolysis.¹⁶

The interaction of several factors in food preparations influences variations in the *in vitro* rate of starch digestion. The degree of gelatinization, cooking techniques, food source, and macronutrient composition were by far the most significant factors.⁴ The higher starch digestibility index observed in OP is due to redistribution of starch fractions resulting in significantly lower resistant starch compared CP. This is also the reason for a significant rise in the values of rapidly available glucose (RAG) which represents the amount of glucose that can be available rapidly for absorption after a meal. Because of its high-water absorption capacity, soluble dietary fibers of oats functions through modifying the food microstructure thereby preventing starch gelatinization aided by limiting the amount of water accessible to starch granules in the food matrix. Since RAG is the total of RDS and free sugars found in the food, it is believed to be useful in predicting glycemic responses *in vivo*.^{1,17}

The starch fraction which is hydrolyzed between 20-120 minutes is termed as SDS and acts as an intermediate between rapidly digestible starch

and resistant starch. This fraction is primarily important to maintain slow and sustained release of glucose from food by virtue of its ability to undergo slow and complete digestion through the length of the small intestine. Thus, higher SDS not only influences glucose metabolism and satiety positively but also reduces GI of foods.^{6,18,19} In the present study, the significant increase in SDS content observed may result in providing prolonged and sustained glucose release despite increase in RDS and decrease in resistant starch. This observation is in good agreement with an earlier study wherein, incorporation of oats in traditional Indian preparations such as idli, dosai, upma and chapathi increased SDS content proportionately to the level of oats incorporation.⁶

When foods are exposed to conditions that increase starch susceptibility to enzymatic activity, starch digestibility increases.²⁰ While oat flours have been reported to inhibit starch digestibility, resulting in lower GI in foods,²¹ in the present research, the percent starch digested was negatively linked to soluble dietary fiber content, so SDI did not correlate with the fiber content of the developed food products. The findings indicate that, in mixed food formulations, soluble fiber has limited influence on the rate of starch digestibility, given the fact that several other factors affect the rate of food digestion.

Furthermore, the viscosity of various soluble fibers varies, as do their ability to slow carbohydrate digestion and absorption.^{22,23} It is noteworthy that oats incorporation at a high level of 20% did not result in any off taste, aroma, mouthfeel and aftertaste and scored high in terms of color, appearance and overall acceptability compared to control pongal making it suitable medium to increase soluble fiber content without affecting starch digestibility index.

Conclusions

Incorporation of oats in pongal offers a new therapeutic dimension where easily digestible foods having high energy density foods are warranted. Oats incorporated pongal can be made part of the diets in febrile conditions requiring ease of digestion with added benefits of meeting dietary fiber requirements because of the therapeutic importance of β -glucan present in oats which helps in combating many nutritional disorders and restoring gut microflora.

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Conflict of Interest

The authors do not have any conflict of interest.

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