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In vitro Starch Digestibility Characteristics of *Dioscorea alata* Tuber

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Abstract: The present investigation evaluated the effect of processing on the nutritionally important starch fractions and the extent of *in vitro* starch digestibility in *Dioscorea alata* tuber, using controlled enzymatic digestion with pancreatin and amyloglucosidase. The tuber was subjected to three processing treatments viz., open pan, pressure cooking and steaming. The total starch content ranged between 7.87%-10.27%. Steaming resulted in significant increase ($p < 0.05$) in total starch content and RAG value. The cooking methods did not contribute much towards the redistribution of starch fractions and the SDI value did not differ significantly among three different cooking methods. Although cooking of the tuber significantly decreased ($p < 0.05$) amylose content no significant difference was observed between three cooking methods used. Results suggest that, pressure cooking can be used as a method of choice for the cooking of *Dioscorea alata* tuber as it led to lower RAG value.

Key words: Starch fractions % *Dioscorea alata* % Processing % *in vitro* digestibility

INTRODUCTION

Dioscorea alata is wide spread in distribution being grown in tropics and subtropics of Africa, America, Asia and Caribbean [1-2]. The tubers are nearly always single and very large weighing upto 60kg and measuring upto 2 meter in length [3]. The dry matter of the yam tuber varies between 20-40% of which inturn consist of 60-80% of starch depending on the variety [4]. Starch is the major carbohydrate reserve [5] found as granules typically consisting of 10-30% amylose and 70-90% amylopectin [6]. The starch from *Dioscorea alata* has high amylose content, high intrinsic and apparent viscosity and low gelatinization enthalpies [7]. On storage the starch content was found to decrease to an extent of 20-30% [8]. Yam tuber may be stored for several months but sprouting is accompanied by considerable loss of dry matter and water [4]. The tuber is used in number of ways such as soup thickener, as fried chips and as fried mashed yam balls, it is also used in baked products as reconstituted dough and yam flakes [9].

Although yam starch has potential as thickening and gelling agent in food, its commercial application is limited as publications on this starch are fewer in relation to those of corn starch [4, 10]. However yam starch is being studied as an alternative source because of its several desirable properties such as stability to high temperature and low pH [11]. In view of this, the present study was planned to evaluate the effect of processing on nutritionally important starch fractions and amylose in *Diascorea alata* tuber.

MATERIALS AND METHODS

Materials: *Dioscorea alata* tuber (DA) was collected from Western Ghats, India. Amyloglucosidase (A9913, Sigma Aldrich, India), Pancreatine Porcine (P1750, Sigma Aldrich, India), Invertase (RM 5983, Himedia, Mumbai, India), Glucose oxidase-peroxidase reagent kit (Span Diagnostics, Surat, India) and Potato Amylose (RM 1469, Himedia, Mumbai, India) were used. All the chemicals and reagents used in the study were of extra pure analytical grade.

Sample Preparation: The tuber was washed and the non edible portion (peel) was discarded. Edible portion was divided into three equal portions and subjected to three processing treatments and used for the analysis of starch fractions. The same portions after drying are used for the estimation of amylose. Each food was studied in three replicates.

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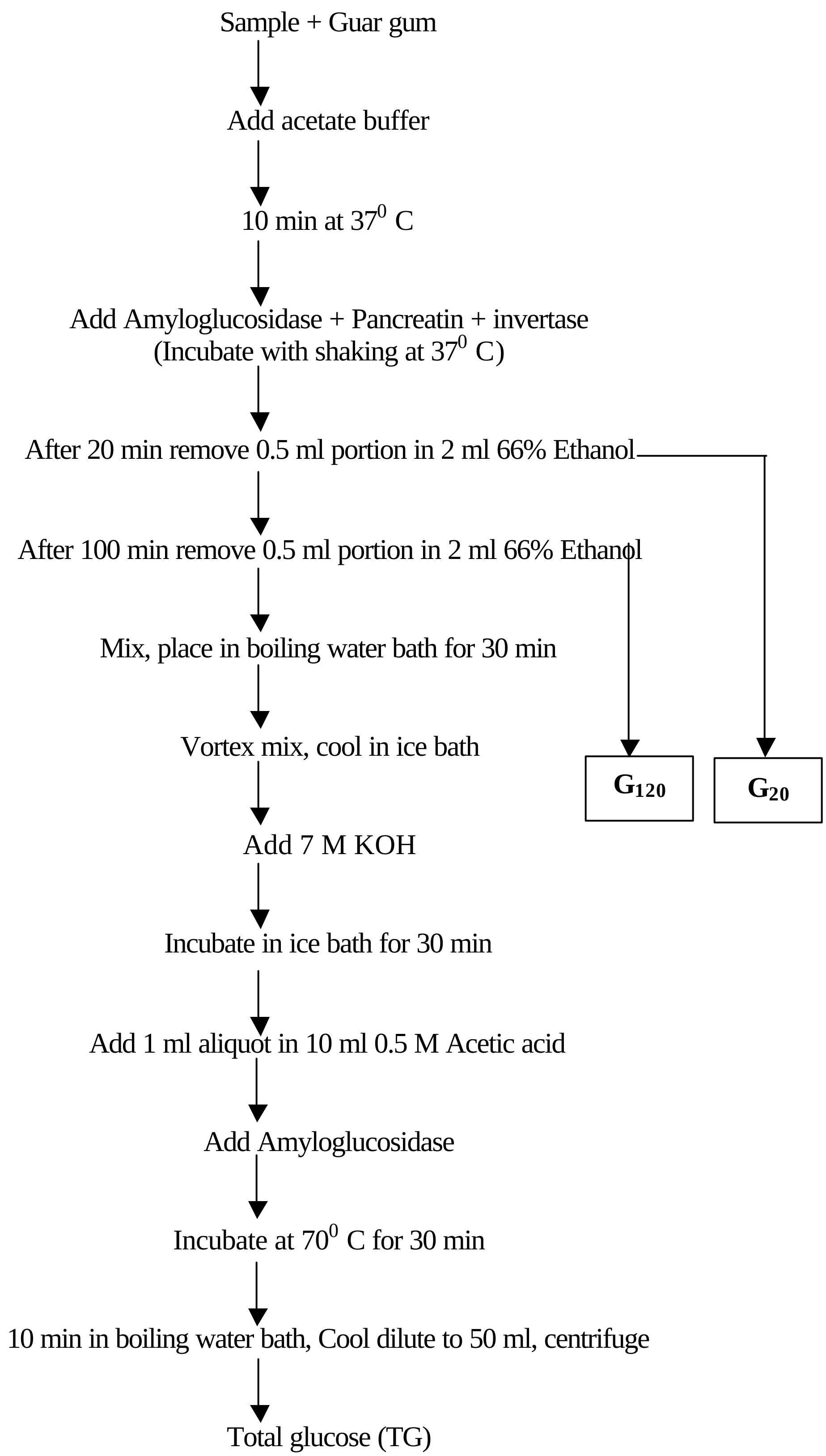

Fig. 1: Summary of the analytical strategy for measurement of starch fractions

Processing Treatments

Open Pan Cooking: The cut vegetable pieces (100g) were cooked in an open pan for 10 min (till done) using enough water (200 ml).

Pressure Cooking: The diced tuber pieces (100g) were pressure cooked (9.8 x10^4 pa) with enough water (200ml) for 4-5 min and used for analysis of starch fractions.

Steaming: The diced tuber pieces (100g) were steamed in a closed container for 4-5 min and used for analysis of starch fractions.

Starch Fractions: The various starch fractions (TS: total starch, RDS: rapidly digestible starch, SDS: slowly digestible starch, RS: resistant starch) were measured in processed food samples after incubation with invertase, pancreatin and amyloglucosidase at 37°C in capped tubes immersed in a shaken water bath [12]. Since foods normally require chewing they were minced by standard procedure, the incubation tubes contained glass balls for disrupting the food particles and guar gum was added to standardize the viscosity of the incubation mixture. A value for RAG was obtained as the glucose released after 20 min (G_{20}). A second measurement (G_{120}) was obtained as glucose released after the further 100 min incubation. A third measurement (total glucose; TG) was obtained by gelatinization of the starch in boiling water and treatment with 7 M KOH at 0°C, followed by complete enzymatic hydrolysis with amyloglucosidase. Resistant starch was measured as the starch remained unhydrolyzed after 120 min incubation. Free glucose (FG) was also determined by treating the sample with acetate buffer and placing the tube in water bath at 100°C for 30 min. Simultaneous tests were run in a similar manner with glucose standard. A blank tube containing buffer, glass balls and guar gum was also included to correct for the glucose present amyloglucosidase solution. A summary of the analytical strategy used is shown in Figure 1.

Treatment of Data: The values for TS, RDS, SDS and RS were calculated from the values of G_{20}, G_{120}, FG and TG as follows.

- TS = (TG-FG) x 0.9
- RDS = (G_{20} – FG) x 0.9
- SDS = (G_{120}- G_{20}) x 0.9
- RS = TS – (RDS + SDS) or (TG – G_{120}) x 0.9

The relative rate of starch digestion was calculated as follows.

$$\text{SDI} = \frac{\text{RDS}}{\text{TS}} \times 100$$

RAG = Free glucose + glucose from sucrose + glucose released within 20 min incubation. i.e., RAG = FG + glucose from sucrose + G_{20}

Amylose: The Amylose content was analyzed both in raw and processed samples by the method of Juliano et al. [13], which is based on the starch-iodine blue complex.

Statistical Analysis: The data on different starch fractions and amylose expressed as mean ± SD was analyzed by ANOVA followed by Tukey's test multiple compressions using SPSS 14.0 computer software. The values were considered significant at *p*#0.05.

RESULTS

Nutritionally Important Starch Fractions of Dioscorea Alata: Total starch and its fractions, RDS, SDS and RS in the selected tuber are shown in Table 1. All values are expressed in g/100 g on an as-eaten basis. Steaming resulted in a significant increase (*p* # 0.05) in total starch content. The total starch content was found to be highest in steam cooked sample followed by open pan and pressure cooking. The starch fractions were found to vary depending on the method of processing to some extent.

Rapidly available glucose and starch digestibility index: Rapidly available glucose (RAG) and starch digestibility index (SDI) of the *Dioscorea alata* are shown in Table 1. The RAG values differed significantly (*p* # 0.05) among three cooking methods studied. Steaming of the tuber resulted in significantly high RAG value (9.45±0.18) followed by open pan (7.30±0.34) and pressure cooking (6.45±1.03). On the other hand no significant differences were observed with respect to SDI values of *Dioscorea alata* tuber subjected to three different cooking methods. SDI represents the relative rate of starch digestion.

Amylose: Raw sample contained significantly higher (*p* # 0.05) amylose than the processed samples (Figure 2). The raw sample contained 15% amylose where as the amylose content of processed samples ranged between 8.2 to 8.9%. Although the amylose content of processed

Table 1: Total starch and its fractions SDI and RAG in *Dioscorea alata* [mean± SD g/100 g]

Sample	Dry matter %	TS	RDS	SDS	RS	SDI	RAG
Open pan	21.2	8.83^{b}±0.37	6.27^{a}±0.28	2.53^{b}±0.28	0.28^{a}±0.13	70.9^{a}±2.1	7.30^{b}±0.34
Pressure cooking	21.1	7.87^{a}±0.29	5.49^{a}±0.93	0.94^{a}±0.90	1.55^{b}±0.36	69.6^{a}±10.4	6.45^{a}±1.03
Steaming	21.3	10.27^{c}±0.22	8.09^{b}±0.15	0.10^{a}±0.01	2.15^{c}±0.16	78.9^{a}±0.40	9.45^{c}±0.18

*Mean values carrying different superscript letters a, b, c….., in columns differ significantly (*p* # 0.05)

[#] TS: total starch, RDS: rapidly digestible starch, SDS: slowly digestible starch, RS: resistant starch, SDI: starch digestible index and RAG: rapidly available glucose

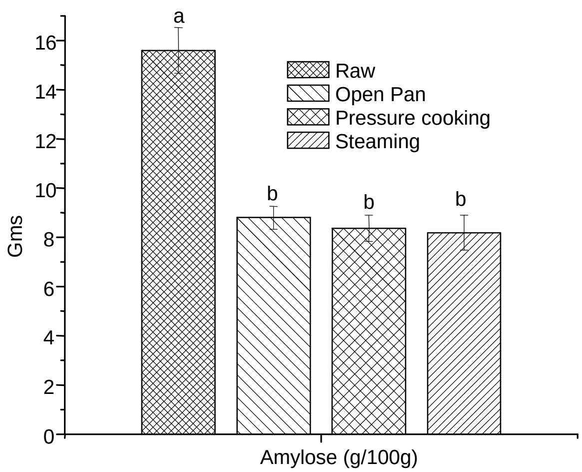

Fig. 2: Effect of processing on the amylose content of *Dioscorea alata*
*Bars carrying different superscript letters a, b, c….., in differ significantly (*p* # 0.05)

samples was significantly lower (*p* # 0.05) than raw sample, amylose content did not differ significantly (*p* # 0.05) between the samples processed using three different cooking methods.

DISCUSSION

Measurement of different starch fractions provides a means for predicting the rate and extent of starch digestion in the human small intestine [12,14]. It is of importance that the *in vitro* procedure should simulate starch digestion at the best possible rate. In the procedure used, foods are analyzed with minimal pre-treatment on an as eaten basis. The present study, reports the effect of processing on nutritionally important starch fractions and amylose in *Dioscorea alata* tuber subjected to three different cooking methods.

The results showed that total starch and its fractions (RDS, SDS, RS) varied significantly depending on the cooking method. Although the three cooking methods had a significant influence on total starch and its fractions, it did not contribute much towards the redistribution of starch fractions. The values obtained for different starch fractions were in accordance with their TS content. Although significantly higher amount of TS was found in steamed tuber, it also contained higher amount of RS compared to open pan cooking and pressure cooking, which might be due to difference in the mode application of heat specifically a greater increase of temperature (170-180°C) is known to occur while stemming which might have increased the total starch content causing higher gelatinization of the starch molecules thereby increasing the available starch content.

Cooking increases susceptibility of starches to hydrolysis, a wide variation in the level of starch modification exists, depending on the processing intensity and storage conditions [15]. The most important parameters are the water content and the maximum temperature reached. Baked and mashed potato preparations whose physical form has been disrupted, had a higher *in vitro* digestibility compared to boiled potato [16]. The food form and the degree of cooking also have a marked effect on the rate of starch digestion [17]. The heat used during cooking can be dry as in baking or wet as in boiling and steaming. Heat increases the nutrient availability. Processing may also reduce the nutritional value of some root crops as a result of losses and changes in major nutrients [18].

The RAG represents the amount of glucose that can be available rapidly for absorption after a meal. It is the sum of RDS and free sugars that are present in the food. Hence its usefulness is reported in predicting the glycemic responses to carbohydrate foods [12]. Steaming of the tuber resulted in a significantly higher RAG followed by open pan and pressure cooking. However, SDI values did not differ significantly among three cooking methods studied. SDI is a measure of the relative rate of starch digestion. The lowest SDI value was seen in pressure cooked tuber and a significant positive correlation (r = 0.860) was also observed between RAG and SDI values. Some studies also have shown similar positive correlation between RAG and SDI in rice [19].

CONCLUSION

The results emphasize that, the three cooking methods viz., open pan, pressure cooking and steaming influence the total starch and its nutritionally important fractions in *Dioscorea alata* tuber. The data generated will be useful in including the selected sample in the diets of diabetics as RAG values, which are based on a given weight of food as eaten, can be used directly in the calculation of the total RAG value for a meal. Pressure cooking can be used as a method of choice for the cooking of *Dioscorea alata* tuber as it led to lower RAG.

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