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Process Optimisation for Ready to Eat Tapioca (*Manihot esculenta* Crantz) in High Impact Polypropylene Containers

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Abstract

Tapioca is a traditional food and is considered as a delicacy in Kerala when taken along with fish curry. Edible tapioca was blanched in 0.1% guar gum and packed in HIPP containers by hot filling the brine solution. Dynopack sealing machine was used for sealing the top of HIPP trays using polyester coated with silicon dioxide/ nylon/cast polypropylene. They were processed in still water immersion retort at 121.1°C for different F_0 values of 5, 6, 7 and 8 minutes. Based on the results of sensory evaluation and tests for commercial sterility an F_0 value of 7 was optimised for the product. Upon thermal processing significant decrease ($P<0.05$) in hardness and chewiness was observed for tapioca.

Key words: Water immersion retort, tapioca, thermal processing, high impact poly propylene (HIPP) containers.

Introduction

Cassava is a tropical root crop widely cultivated and utilized in 102 countries of the world. It has several health benefits like ability to help in healthy weight gain, increase circulation and red blood cell count, protect against birth defects, improve digestion, lower cholesterol, improve metabolic activities, protect bone mineral density, prevent Alzheimer's disease, protects heart health and maintains fluid balance within the body. It is therefore necessary to make every possible effort to make them available in fresh or preserved form for human consumption with availability throughout the year. Consumers are becoming increasingly aware of the nutritional content, toxic factors, microbiological quality and preservative free products while purchasing food. Preservation of food by thermal processing especially in retortable pouches will help in providing preservative free products with extended storage life as well as improved nutritional benefits compared to metal containers. Retort pouches having three layer configuration of polyester/aluminium foil/cast polypropylene can perform the packaging function as that of metal cans and is free from disadvantages like poor barrier properties, pin holing, poor seal strength etc (Srinivasa Gopal et al., 1998). Studies have shown that fish curries packed in retortable pouches and processed in steam air mixture using over pressure autoclave found to be in acceptable condition for more than one year at ambient storage (Srinivasa Gopal et al., 2001; Ravishankar et al., 2002; Mohan et al., 2006, 2008, 2014 & 2015; Sonaji et al., 2002; Manju et al., 2004). Compared to steam-air retorts, water immersion and still water spray retorts are found to be advantageous as the air pockets inside retort will not be formed in latter types. Faster heating rate and better nutrient retention is another advantage of using water spray and water immersion retorts. Of late semi-rigid containers are gaining importance for thermal processing. The advantages of these semi rigid containers are they can be formed in any shape i.e., round, square, rectangle, hexagonal etc with varied depth for different volumes. Apart from this, they can be used as eating bowl due to their rigidness. These containers are either made of multi-layer with many layers of polypropylene and ethylene vinyl alcohol or with High Impact polypropylene (HIPP). Semi-rigid containers made of HIPP are found to be suitable for food contact applications and had good barrier properties (Mohan, 2008). It can also be made locally and are cheaper compared to many commercially available containers. The cooked edible tapioca root as such or in combination with fish curry is consumed widely in most households in Kerala and forms a staple diet in certain places. These are high moisture foods and have a limited storage life at ambient temperature. In order to ensure their distribution and long term storage, it is necessary to preserve them suitably. Hence in this study attempts have been made to standardize process parameters for the development of ready to eat tapioca in thermoformed containers which can be stored at ambient temperatures by subjecting the products to thermal processing using water immersion retort (Fig. 1 & 2).

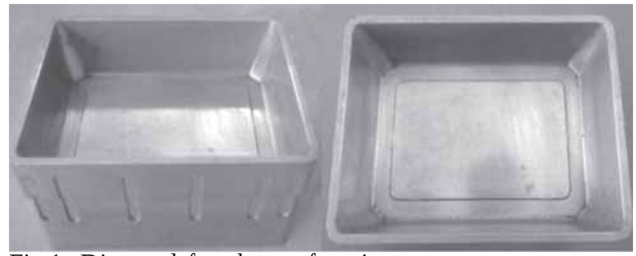

Fig.1. Die used for thermoforming

Fig. 2. HIPP sheet for thermoforming

Materials and Methods

High impact polypropylene (HIPP) tray forming

Thermoformed containers are made by vacuum forming equipment (K. L. Thermoformers Private Limited C-67/2, Okhla Industrial Area, Phase-II,New Delhi-110029. India). The equipment consists of a vacuum box with an air outlet and a clamping frame, a mould, a heating panel and a vacuum pump. The mould, which is partly hollow underneath and is perforated, is placed over the air outlet. The thermoplastics sheet is cut and placed over the open top of the vacuum box and securely clamped by means of frame giving an airtight compartment. Provision to set the heating temperature and time of holdings and can be adjusted. The sheet is heated until rubbery. The heater is withdrawn, and air in the box is rapidly evacuated by the vacuum pump. Atmospheric pressure above the sheet forces it down into close contact with the mould where it is cooled sufficiently to retain its shape. The clamping frame is then released, the formed sheet is removed from the mould, and the excess material trimmed off manually by an attachment provided with blade to cut the excess sheet (Fig. 3).

Fig.3. Thermoforming machine

Processing

Tapioca variety Malayan 4 (*Manihot esculenta* Crantz) was purchased from the local market of Cochin, India were washed in potable running water, peeled, cleaned and cut into cubes of uniform size. After thorough washing, the cubes were blanched at a temperature of 95ºC in a solution containing 0.1% guar gum for 2 minutes to reduce the leaching of amylose. In the initial trials, the samples processed without the addition of guar gum resulted in cloudy appearance of the brine solution. Hence the guar gum (0.1%) was used to overcome this. After blanching the cubes were immediately cooled to prevent excessive cooking. The tapioca cubes, 100g each with 110 ml of 2% hot brine were packed in HIPP containers of size 12.5 x 9.2 x 2.5cm (length x breadth x height) and sealed immediately using a film of cast poly propylene/polyester/ silicon dioxide/nylon using heat sealing machine (Dynopack, Dynopack Industries, Hyderabad, India). Initially the cold point in the water immersion retort was standardized by placing thermocouples of Ellab SSA-12050-G700-TS stainless steel electrode with a length of 50 mm, diameter 1.2 mm in different positions of the retort and heat penetration studies were carried out by monitoring the temperature of the product placed in the cold point. Minimum three containers were fixed with glands and thermocouples, the tips of which were inserted into a cube of tapioca. The filled and sealed trays were laid flat on the trays in a water immersion retort (Lakshmi Engineering Works, Chennai, Tamil Nadu, India). The processing media was water sprayed at a high pressure (28psi) inside in a mist like formation, collected at the bottom, directed to a circulation line. Steam is admitted into the circulation line and also directly inside the retort. The sprayed water absorbs the heat from incoming steam and transmits the same to the products. The thermocouple output was measured using an Ellab E- Val Flex, 14592 data recorder. The retort temperature was maintained at 121.1^{0}C and the trays were processed to F_0 5, 6, 7 and 8 minutes.

The F_0 value for the tapioca was optimized and then pilot scale production was done for carrying out storage studies at room temperature. The samples were analysed at regular intervals of 30 days.

Rapid cooling was done by cutting off the steam supply and recirculation of cooling water. The trays were unloaded from the retort when the core temperature reached around 30ºC. The recorded data was analyzed and heat penetration data were plotted on a log paper with temperature deficit (retort temperature–core temperature) against time. Lag factor for heating (J_h), slope of the heating curve (f_h), initial temperature deficit (I), final temperature deficit (G), time in minutes for sterilization at retort temperature (U), lag factor for cooling (J_c) and cook value (C_g) were determined. The Ball's process time (B) was calculated by Formula method (Ball 1923). Total process time (T) was determined by adding Ball's process time (B) and the effective heating period during come up time i.e., 58% of the come up time. (Stumbo 1973)

Ball's Process time (B) = f_h[log (IxJ_h) –log g]

Total process time (T) = B + 58%of come up time

The moisture content of tapioca and the proximate composition of mackerel used for the study were determined as per AOAC methods (2000). The amount of amylose and amylopectin present in tapioca was estimated using the method of Gilbert and Spragg (1964). The amount of starch and sugar present in the tapioca used for processing was determined as given by Moorthy and Padmaja (2002).

Commercial sterility

Commercial sterility of the processed samples were tested as per IS: 2168 (1971) to assess the adequacy of lethality.

Texture profile analysis

Texture profile analysis were carried out every 30 days during the storage study using the food texture analyzer (Lloyd Instruments, Model LRX plus F.T-39 No-2, UK) with the help of Nexygen software. Tapioca cut in to 2 cm^3 cube was used for texture analysis. Cylindrical probe with 50mm diameter was used for texture analysis at a speed of 12 mm sec^{-1} using 500 N load cell. Compression of 40% was used. In the case of raw tapioca due to its hardness the load cell of 500N was not sufficient and thus 5KN load cell was used.

Colour analysis

Colour measurements were done every 30 days during the storage and was studied using a Hunter lab Colorimeter (Miniscan XE Plus, Model No D/ 8-S) with geometry of diffuse / 8° (sphere 8 mm view) and an illuminant of D65/ 10 deg for parameters L*, a* and b* values. +a value indicates redness and -a is greenness. In the case of b* values +b is yellowness and -b indicates blueness.

Sensory evaluation

Sensory evaluation based on characterization and differentiation of the various sensory characters such as colour, flavour, texture and overall acceptability were evaluated by a panel of 10 trained judges on a 10-point scale (IS: 6273(II) 1971) at regular intervals of 15 days during the storage study. The softness of the tapioca upon thermal processing was also evaluated by the sensory panelists to assess its suitability. The panelists were asked to assign a score of 1–10 as prescribed by Vijayan and Balachandran (1986). A sensory score of 4.0 was taken as the margin of acceptance.

Statistical analysis

Experimental results are expressed in mean ± standard deviation. A minimum of three containers were monitored for time temperature data. Triplicate samples were used for all the biochemical and physical analysis. A minimum of ten samples were used for testing packaging materials. Analysis of variance (ANOVA) was used to define the significance of differences. Significance of differences were established at $P < 0.05$.

Results and Discussion

High impact poly propylene tray forming

The optimum conditions for the thermoforming of High Impact Poly Propylene trays are given in table 1.

Table 1. Conditions for thermoforming

Process Parameters	Setting limit
Heater -1	398°C
Heater-2	395°C
Heater-3	389°C
Heating time	30 sec
Holding time	15 sec
Forming time	20 sec
Cooling time	10 sec
Ejection Time	10 sec

The water immersion retort showed uniform heating in all parts of the processing chamber with a variation of only ±1°C. Tapioca in brine medium packed in trays was heat processed for F_0 5, 6, 7 and 8 min. The tapioca processed at both F_0 7 and F_0 8 was found to be sterile but those processed at F_0 7 was found to be more acceptable than F_0 8 in terms of texture. The tapioca processed for an F_0 8.0 min was felt softer by the sensory panellists compared to product processed at F_0 7.0 min. The tapioca processed at F_0 5 and 6 were not suitable as they were not sterile commercially. In the preliminary study (results not given), the tapioca was processed without adding guar gum resulted in very soft textured product which could be due to the leaching of amylose. In the present study, guar gum (0.1%) was added to overcome this problem. The fresh unprocessed tapioca had amylose content of 18.21 g $100g^{-1}$, which decreased to 15.82 and 12.63 g $100g^{-1}$ upon thermal processing at F_0 7 and 8 min, respectively. The retention of higher amylose content in the tapioca processed at F_0 7.0 min indicates effectiveness of guar gum addition along with heat treatment. The addition of guar gum also resulted in firm texture for the tapioca cubes by preventing the leaching of solids into the brine. This could be due to the uniform deposition of the guar gum on the tapioca preventing leaching of amylose from the product.

The heat penetration characteristics of tapioca in brine medium processed to F_0 7.23 is shown in Table 2.

Table 2. Heat penetration characteristics of tapioca

Parameters	Tapioca F_o - 7.23
J_h	1.01
J_c	0.89
f_h	10 minutes
U	7.23 minutes
f_h/U	1.38
G	0.5235
B	22.35 minutes
CUT	7minutes
TPT	26.41 minutes
Cg	57.89 minutes

Where, J_h = lag factor of heating, f_h = slope of heating curve, U = time in minutes for sterilization at retort temperature, g = final temperature deficit, B = Ball's process time, CUT = come up time, TPT = Total process time, Cg = Cook value.

The come up time to attain 121.1°C was 7 minutes. The come up time should be kept as short as possible (Editor, NCA, 1968). The actual process time for the processing of tapioca to F_0 7.23 was 26.41. The core temperature, retort temperature and F_0 of the process is shown in Figure 4. The retort temperature shows a sudden decrease as soon as the steam was cut off and cold water was circulated. This is necessary because the product should be cooled as soon as possible to avoid overcooking and to prevent growth of thermophiles. The heat penetration characteristics with respect to cook value is presented in Fig. 5.

The proximate composition of tapioca was estimated and the results showed that the tapioca used for processing had a moisture content of 61 ± 0.13%, starch content of 27.55 ± 0.04g/100g and sugar content of 3.74 ± 0.02g/100g.

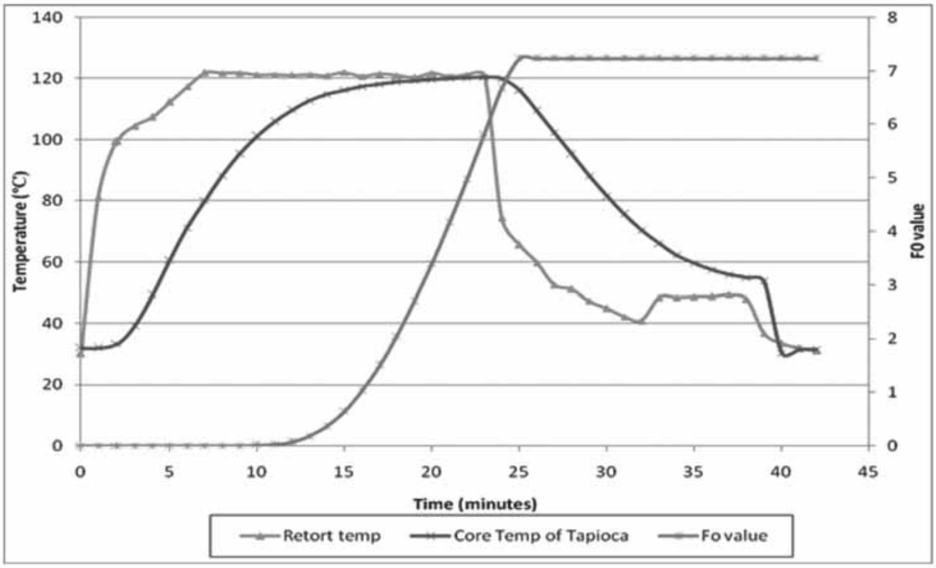

Fig.4. Heat penetration and F_0 value of tapioca in brine

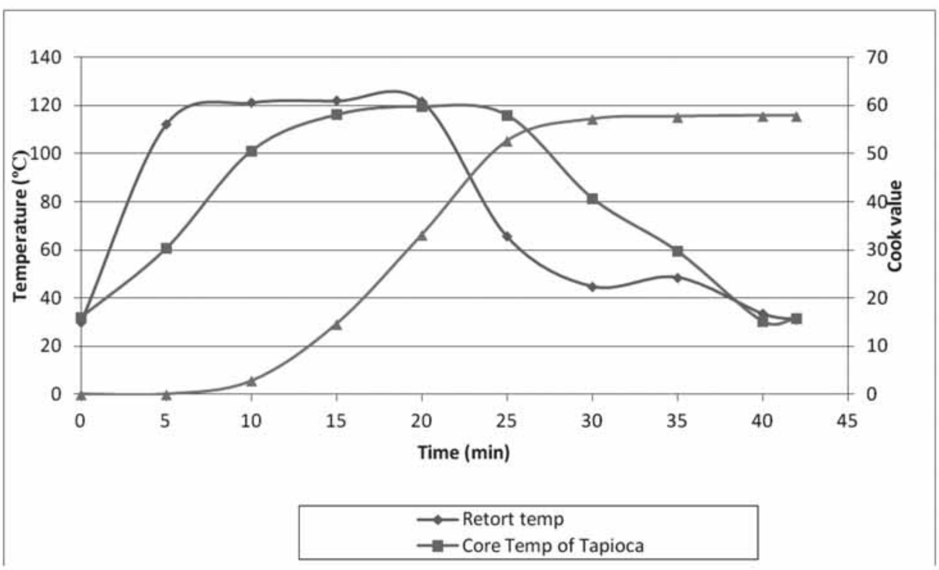

Fig.5. Heat penetration and cook value of tapioca in brine

Texture profile and colour analysis

The different parameters measured by texture profile analysis of tapioca in brine, processed for F_0 7 is given in Table 3. The hardness and chewiness of tapioca decreased significantly ($P < 0.05$) upon thermal processing and there was slight increase in the cohesiveness and springiness. The gumminess was almost same showing no changes due to thermal processing. It is evident that cooking leads to softness. Hardness 2 values are always less than those values obtained at first compression. This is because of the non-compressed sample having a firm texture compared to compressed sample. Table 4 also shows the colour values for tapioca before and after processing. The L* and b* values of tapioca decreases on thermal processing whereas there is a slight increase in the a* value. This is due to the heat induced reactions that occurs during thermal processing. During storage period, an increasing trend for a* values

Table 3. Parameters measured by texture profile analysis of tapioca in brine

DAY	Hardness 1 (N)	Hardness 2 (N)	Cohesiveness	Springiness (mm)	Gumminess (Kgf)	Chewiness (Kgf mm)
0^{th}	622.33 ± 7.00	271 ± 27.87	0.03 ± 0.003	4.18 ± 0.53	0.24 ± 0.016	10.15 ± 0.46
30^{th}	83.64 ± 1.29	35.53 ± 1.05	0.08 ± 0.003	2.40 ± 0.24	0.17 ± 0.002	0.66 ± 0.0005
60^{th}	44.26 ± 1.11	14.501 ± 0.42	0.05 ± 0.002	3.69 ± 0.38	0.21 ± 0.009	0.665 ± 0.018
75^{th}	40.56 ± 0.62	9.64 ± 0.27	0.07 ± 0.001	2.47 ± 0.38	0.27 ± 0.014	0.64 ± 0.009

Table 4. Colour analysis

Days of storage	L*	a*	b*
0	83.80 ± 0.14	0.04 ± 0.01	22.40 ± 0
30	75.04 ± 0.72	1.36 ± 0.04	19.51 ± 0.15
60	73.29 ± 0.31	1.42 ± 0.04	18.60 ± 0.38
90	71.41 ± 0.16	1.97 ± 0.02	18.10 ± 0.1

and a slight decreasing trend for b* values were observed with the storage period.

Sensory evaluation

The overall acceptability for thermally processed tapioca in brine based on the scores assigned by the trained panelists was 8.8 ± 0.07 on the 15th day of storage which gradually decreased to 5.2 ± 0.05 on the 75th day and 3.4 ± 0.06 on the 90th day. The score clearly shows that the products were highly acceptable during the initial days and had a shelf life of 75 days. The samples were rejected on the 90th day of storage since it crossed the score 4 which is considered as the margin of acceptance.

Conclusion

The optimum conditions for thermoforming of High Impact Polypropylene containers were standardized. HIPP trays were used for the thermal processing of Tapioca using brine as the medium. The process conditions were optimized and storage studies carried out shows that the product had a shelf life of 75 days at room temperature.

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