Development of Commercial Tapioca Pearls used in Bubble Tea by Microwave Heat–Moisture Treatment in Cassava Starch Modification

B. E. A. U. Bulathgama, G. D. M. Gunasekara, I. Wickramasinghe, and M. A. D. Somendrika

Abstract—Bubble tea is a trending food product around the globe and capture a high demand in the high-end market in Asian region as well. This product contains a chewy bubble in enhancing the palatability and the acceptability of the final bubble tea product, which is made with cassava starch. Cassava is an important high caloric tropical food crop, yet has a limited utilization due to its perishability and high cyanide content. Industrial processing of cassava into several food products is one of the most preferred solution for this and thus, tapioca pearl production is also one of the major food application of cassava starch. So the main objective of this study to develop a standardized and much preferred method of tapioca pearl production, and develop a tapioca pearl to be incorporated in bubble tea with higher sensory acceptance, and lower cost. A standard procedure was developed after several trials, and considering the economic benefit, cassava flour incorporated pearls were also tried. The made pearls were subjected to sensory evaluation, proximate composition and cyanide content analysis, as well as texture profile analysis, and finally, the microbiological stability of the product was also checked under refrigerated storage conditions. According to the obtained results, the final product was sensory accepted (p<0.05) over the commercially available product and had a laboratory proven shelf life of 30 days under refrigerated storage conditions.

Index Terms—Bubble Tea, Tapioca Pearls, Cassava Starch, Starch Modification, Heat-Moisture Treatment.

I. INTRODUCTION

Bubble tea, is also called the Boba (Bubble in Chinese) tea is a Milk tea beverage, which incorporates tapioca pearls in it. [1] The original, earliest version of bubble tea was made with, hot black tea, large pearl tapioca, condensed milk, and honey. But in the present context there is a huge variation in the products where bubble tea is prepared, hot or iced, with or without milk, with fruit flavoring and many other juices, and several types of bubbles incorporated. Usually Bubble tea is served in a cup and drunk with a large straw, where the tapioca pearls are slurped up, while the tea is sipped. [2] The main raw material in interest of the study; Tapioca pearl is made out from cassava starch. Which is a product from the readily available important food crop of tropics, cassava. But cassava has a very low utilization due to its perishability and cyanide content.

And therefore the production of these tapioca pearls from cassava starch has a much higher significance, as to reduce

Published on January 30, 2020.

Authors are with the Department of Food Science and Technology, University of Sri Jayewardenepura, Sri Lanka.

the post-harvest losses and the toxicity of cassava as well as to increase the utilization of this unexploited food crop, processing of cassava act as the utmost solution. Where the cassava tubers are converted into several different other forms, which mainly include cassava starch and cassava flour. [3] Flour or starch from cassava tubers, are utilized in the preparation of various food gels, snacks and baked goods. [4]

The native cassava starch (the product extracted from cassava roots by the starch extraction process, unlike flour and which contains not less than 90% starch in dry basis) has limited variations in its structure and properties and therefore is usually modified to diversify the structure and functionality to suit in number of diverse applications. Starch modification is done in three basic ways; Chemical, Physical and Genetic. [5] By chemical modification a tapioca starch may converted to any commercial derivative available currently, as same as with the other starches. And when comes to the genetic modification of cassava starch, it is a cost-effective tool for modifying starch structure and functionalities, where The physical modification includes the application of shear force, or thermal treatment. [6] Many extruded products and snacks were produced with combinations of these means. The physically modified cassava starches are the alpha starch and heat moisture treated starch. [7] Heat-Moisture treatment was the oldest physical modification practiced on the cassava starch. To initiate the production, the settled starch in the starch extraction which is about 50% moistened and then dried on a hot floor at 50-80°C. This starch has remarkably different pasting properties to that of native starch.[8] Tapioca pearls are pearls formed in spherical shape and are a mixture of gelatinized and un-gelatinized starch produced by heatmoisture treatment.[9] even though there is no standardized procedure in making tapioca pearls, the current methods in practice has some common steps, which can be generalize as, moistening the starch up to 50% moisture and then given a mechanical shaking to form sphere shapes. The spherical shaped starch is then undergone with a two-step heating where it is roasted in a rotary dryer at about 200-300°C and then cooled and again undergo a secondary drying of 50-60°C before packing. The final product is a fine pearl, which is fragile when given a little force. And when the product is cooked just before adding to the bubble tea, it acquires a transparent, chewy, gel like nature.

The study focuses on introducing a modified and standardized process in producing tapioca pearls, and also to develop a much commercial viable, raw product with higher ability to withstand the pressure in rough handling, and

higher sensory preference after cooking.

II. MATERIALS AND METHODS

A. Sample collection

The Kirikawadi cultivar of cassava was obtained from the Agricultural Research Station, Department of Agriculture, Thelijjawila, Sri Lanka. Then carefully stored in the refrigerated conditions after packing and sealing in air tight containers.

B. Flour and Starch Extraction

Cassava flour and starch extraction was carried out, through general procedure.

C. Tapioca pearl production (modified method)

After several trials, the pearls were made through the modified method described further as the gelling method.

Initially, a starch slurry was prepared by mixing 5g of native starch with 30ml of water and the filtered through a muslin cloth. Then it was boiled in a 100°C water bath until the slurry become a transparent Gel. Then the Gel was mixed with Native Starch of Flour in 1:2, 1:3 and 1:4 ratios, to form Spherical shapes of 1cm diameter. A non-sticky and soft pearl was obtained by the 1:3 ratio dough. Then the prepared pearls from both starch and flour was secondary heat treated with Microwave treatment at Mid-low power for 2 minutes which was selected as to a primary study of the researcher. [10]

D. Proximate composition analysis and cyanide content analysis

The proximate composition of the developed tapioca pearls was analyzed by the AOAC methods; Moisture content by oven drying method (AOAC 925.10), Total fat content by Soxhlet method (AOAC 922.06), Protein Content by Macro Kjeldahl method (AOAC 978.10), Total ash content by Muffle furnace method (AOAC 923.03), Crude fiber content by (AOAC 978.01) and total Carbohydrates were calculated by the difference method. (Total Carbohydrate % =100% - (Fat%+Protein%+Ash%+Crude fiber%+Moisture %)). And the cyanide content was determined by the picric acid method of spectrophotometric determination.

E. Sensory evaluation

All the pearls were cooked in 100°C boiling water for 20 minutes. And then was added to plastic transparent cups with chocolate flavored UHT milk, and subjected to evaluate their appearance, mouth feeling, flavor, chewiness, texture and overall acceptability by 30 members of a semi trained sensory evaluation panel from the Department of Food Science and Technology, University of Sri Jayewardenepura.

Panelists were informed that they would be evaluating cassava pearls like in bubble tea, and they were presented with three-digit code number labels (coded "000"). The order of presentation of the cassava bubbles was also random. The panelists were asked to evaluate the samples according to their preference. Samples were evaluated using a 5-point hedonic scale, with 1 for "extremely dislike" and 5 for "extremely like". Water and unsalted crackers were

provided to panelists to cleanse their palates between samples. Data acquisition was done using "Minitab 17 Statistical Software".

F. Texture profile analysis

Both the raw and cooked pearls were analyzed for the texture profile by two-cycle compression, in CT3 texture analyzer (50 kg, Brookfield, USA). The method for texture profile analysis was used as recommended in Brookfield's instruction manual. The texture analyzer was supplied with a load cell of 100g and application software (Brookfield Texture PRO CT). Two successive compressions were carried out on each sample. The resulting force-time curves were developed for hardness, deformation, adhesiveness, cohesiveness, resilience and springiness. The accessory used for all measurements was a TA11/1000 probe. Each sample was tested two times at the test and return speed of 0.5 mm/sec and target depth of 2 mm. Trigger load was 10.0 g, pretest speed was 2 mm/sec, and data rate was 20 points/sec.

G. Microbiological stability testing

The microbiological testing was done by Total plate count (Nutrient Agar media), Yeast and Mold count (Potato Dextrose Agar media), and coliform testing (Mc Conkey Broth).

III. RESULTS AND DISCUSSION

The selected cassava cultivar; Kirikawadi, which is native to Sri lanka, has a much low shelf life even when compared to other two varieties recommended in Sri Lanka due to its morphological structure, of neck less root formation. [11] This cause the tuber damage while harvesting and therefore much more susceptible to pest attacks and diseases as well to post harvest physiological deterioration (PPD). As the product suggested by the study also expect to increase the post-harvest life of cassava by value addition, this native variety was selected in the study proceedings.

When considering the related products like Sago it has being identified that the ultimate requirement of the tapioca pearl is to give additional sensation to the food product, in which it has being incorporated, with, springiness and chewiness, and the bubble like appearance. These characteristics are imparted to the pearl, by the process called, "gelatinization" of starch, and it can be acquired by proper heat-moisture treatment. As the starch readily gelatinize at $59^{\circ}\text{C} - 65^{\circ}\text{C}$. In the existing method of tapioca pearl production, they tend to have uncooked core, due to lack of pre-gelatinization in the heat-moisture treatment. The developed gel method, overcome this problem, along with some other additional benefits like, ability to stick the native starch in its structure, easiness in forming the spherical shapes with the dough like structure, relatively reduced cooking time in the point of consumption, as a higher amount of the starch is pregelatinized.

Even though it is already known that the gelatinization is a property of starch, even in the developed gel method, incorporating native flour, instead of starch was tried, as obtaining flour is much economical than starch and produce low wastage in the process. But, flour contains, a considerable amount of fibrous compounds other than starches, which may affect in forming the gel structure.

For the sensory evaluation of the product, the products were cooked by supplying the same temperature for same time period with same environmental conditions; 20 minutes at boiling water. [12] Though some samples were not able to withstand the cooking, and therefore was cracked, or partially dissolved in the boiling water, however all the samples were subjected to the sensory analysis. Here as the base UHT Chocolate milk was used, as the commercial product considered to be taken in the benchmarking has a chocolate milk base in it. According to the obtained results, the starch pearls were selected to have the highest preference, and therefore was selected to be incorporated in the final bubble tea product. Then the final product was also sensory analyzed against a commercially available product, with a same kind of sensory panel. In this study, as to the author's experience, and common knowledge, the "Bubble me- Bubble tea" was selected as a competitive and establish bubble tea producer. And from the wide range of tastes, and toppings they are providing, the black tea based chocolate milk bubble tea with black pearl topping was selected, as it contains both the black tea extract, and the tapioca bubbles, and also due to the easy adoptability in comparing with the developed product of the study. The developed tapioca pearl in the bubble tea was preferred over the commercially available one in this sensory evaluation too.



Fig. 1. Radar diagrams obtained for the sensory evaluations A. Sensory evaluation results for cooked tapioca pearls. B. Sensory evaluation results for benchmarking of the final product with commercially available one

As to the p values, the visual sensory attributes; the color and the appearance has shown no significant difference between the two samples. But all other attributes, and the Preferred rank also has shown a significant difference between the two samples, and as to the sum of ranks, the developed product in the research, has gain a much preference over the commercial product.

Even in the attributes, that do not show a significant difference, yet the highest preference was owned by the developed product.

Thus the sensory evaluation gives only non-parametric

data a Texture profile analysis was also carried out to get parametric data on the textural attributes of the developed tapioca pearls. Texture Profile Analysis (TPA) is a widely used approach in the food industry as a rapid and convenient tool to measure the food texture, though the texture is only to be measured by human. In the texture analyzer the motion of the analyzer mimics the action of the human jaw in chewing a food. [13]. In the study the primary TPA parameters, the hardness, deformation, adhesiveness, cohesiveness, resilience, and springiness was measured for both raw, and cooked tapioca pearl samples from starch as well as flour pearls. Hardness is defined as the maximum peak force applied in the first cycle of the analysis which mimics the first bite of a food. And the adhesiveness is the work force required to remove a food particle from the other adhered matrix, if in the human mouth, the teeth, tongue and palate. [14] Cohesiveness is identified as the compression ratios of two cycles. And the length to which the sample recovers in height during the time that elapses between the end of the first compression cycle and the start of the second compression cycle is defined as springiness. [15].

The obtained harnesses were extremely high in raw pearls, made from both flour and starch, which is also preferable in using in the industry with rough handling. But the hardness decreases massively with the cooking, which results in a smooth pearl to be incorporated in food items, bubble tea, in the case of this study.

All the other characteristics of interest, the adhesiveness, cohesiveness, resilience and the springiness highest in the cooked pearls made solely with starch which seconds the conclusion gain through the sensory evaluation.

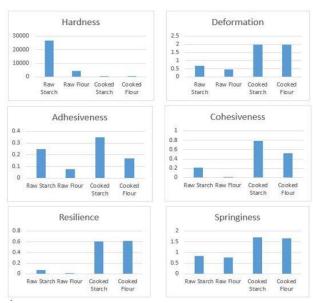


Fig. 1. Primary TPA Characteristics of developed raw and cooked tapioca pearls

The proximate composition and the cyanide content of the developed product was found to be as follows,

1 1	
Moisture	17.96±0.27%
Protein	$1.43 \pm 0.41\%$
Total fat	$0.96 \pm 0.0\%$
Total ash	$0.098 \pm 0.00\%$
Crude fiber	$0.2 \pm 0.00\%$
Carbohydrate	$79.35 \pm 0.00\%$
Cyanide content	5.45 ± 0.059 ppm

And as to the values obtained for the cyanide content it clearly shows that the cyanide content of the raw cassava has been reduced to a safe level by the processing steps involved in the production of the tapioca pearl.

Finally, the product was packaged in polyethylene, kept in a refrigerator, and microbiological stability was checked for 30 days. Any of the tests; Total plate count, yeast and mold count, or coliform test has not shown positive results, within the test period, and therefore the product has a tested shelf life of 30 days in the refrigerated storage conditions.

IV. CONCLUSION

The developed tapioca pearls, has a higher ability to withstand the industrial handling, higher sensory acceptance, lower cyanide content, lower cooking time, and also a considerable shelf life, and therefore can be adopted to the commercial production.

ACKNOWLEDGMENT

B.E.A.U. Bulathgama Thanks the supervisor Professor Indira Wickramasinghe, for the continuous support, knowledge and encouragement, Dr. M.A.D. Somendrika for the support and knowledge, and Colleague G.D.M. Gunasekara for the continuous support given throughout the research and manuscript writing.

REFERENCES

- [1] Shigaki, T. (National Agricultural Research Institute Lae Papua New Guinea). Cassava: The Nature and Uses [Internet]. 1st ed. Encyclopedia of Food and Health. Elsevier Ltd.; 2016. 687–693 p. Available from: http://dx.doi.org/10.1016/B978-0-12-384947-2.00124-0
- [2] Dubrin B. Tea Culture; History, Traditions, Celebrations, Recipes & More. Penn Publishing Limited. 2010. p. 51.
- [3] Wijesinghe WAJP, Sarananda KH. Utilization of Cassava Through Freezing. J Food Res. 2010;(April).
- [4] processing factors affecting the yeild and physiochemical properties of starch from cassava chips and flour. V. Olomo, O.Ajibola. 2003, starch-starke, pp. 108-114.
- [5] Modified starches, properties and uses. Wurzburg, O.B. Boca Ration, Florida: CRC Press Inc., 1996.
- [6] Effect of single and dual heat moisture treatments on properties of rice, cassava and pnaho starches. B.Klein, V.Z. Pinto, L.N. Vanier, E.D. Zavareze, R. Colussi, J.A. du Evangelho, L.C. Gutkoski, and A.R.G. Dias. 1998, carbohydrate polymers, pp. 1578-1584.
- [7] Impact of Heat Moisture Treatment on molecular structures and properties of starches isolated from different botanical sources. Hoover, R. 2010, Critical reviews in food science and nutrition, pp. 835-847
- [8] Sriroth K, Piyachomw K, Sangseethong K, Oates C. MODIFICATION OF CASSAVA STARCH. ŻYWNOŚĆ. 2002;4(33):219–30.
- [9] Breuninger WF, Piyachomkwan K, Sriroth K. Tapioca / Cassava Starch: Production and Use [Internet]. Third Edit. Starch: Chemistry and Technology. Elsevier Inc.; 2009. 541–568 p. Available from: http://dx.doi.org/10.1016/B978-0-12-746275-2.00012-4
- [10] Bulathgama BEAU, Wickramasinghe I, Wijesekara I, Somendrika D. Textural profile analysis 0f granulated cassava pearls of two cultivars treated with conventional and microwave heating. In: 3rd International Research Symposium in Pure and Applied Sciences [Internet]. Research Gate; 2018. p. 41. Available from: https://www.researchgate.net/publication/328802576%0ATextural
- [11] HORDI. Horticultural Crop Research and Development Institute. [Online] 2018. [Cited: 11 20, 2018.] https://www.doa.gov.lk/HORDI/index.php/en/crop-2/47-cassava-e.

- [12] Hirao K, Nishioka I, Setsuko T. Studies on the Cooking of Pearl Starch. 日本家 政 学 会 誌. 1989;40(5):363-71.
- [13] Nishinari K, Kohyama K, Kumagai H, Funamil T, Bourne MC. Parameters of Texture Profile Analysis. Food Sci Technol Res [Internet]. 2013;19(3):519–21. Available from: http://jlc.jst.go.jp/DN/JST.JSTAGE/fstr/19.519?lang=en&from=Cross Ref&type=abstract
- [14] Bhaduri S, M T, KP N, R G. Physical, Textural and Sensory Characteristics of Gluten Free Muffins Prepared with Teff Flour (Eragrostistef (ZUCC) Trotter). J Food Process Technol. 2015;06(09).
- [15] Mochizuki Y. Texture Profile Analysis. Curr Protoc Food Anal Chem. 2001;(1963):1–7.



Ashani U. Bulathgama was born in Colombo Sri Lanka in 1993. And has completed her bachelor's degree in Food Science and Technology at the University of Sri Jayewardenepura in 2019.

She was working at the Lanka Canneries (Pvt) Ltd, as an Executive (Research and Development) till 2019 for six months, and also had an in plant training of four months at the CBL Foods International (Pvt) Ltd attached to the Production Department. She has published a paper titled, "Textural profile analysis of

granulated cassava pearls of two cultivars treated with conventional and microwave heating" at the Third international research symposium on pure and applied sciences organized by University of Kelaniya, Sri Lanka. And another one titled, "Development of tea concentrate to incorporate in bubble tea using refused black tea and assessment of sensory properties and phytochemical composition" in the International Journal of Food science and Nutrition, based on her undergraduate research. Her research interests are mainly focused on the fields of Food Chemistry and Food technology.

Miss. Bulathgama has been awarded with the Best Team player award, and First Runners up in the Best Innovator award at the Employability Skills Awards Ceremony 2018 of University of Sri Jayewardenepura. Also She has been awarded with the Most Innovative Product – First Runners Up at the Pro – Food Pro –Pack International Exhibition 2016 by representing the University.



Dewni M. Gunasekara was born in Colombo Sri Lanka in 1994. She is following her Master's degree on Food Science at the RMIT University, Australia, and has completed her bachelor's degree in Food Science and Technology at the University of Sri Jayewardenepura in 2019.

She had an in plant training of four months at the Ceylon Cold Stores, Ranala, Sri Lanka. She has published a paper titled, "Important Physiochemical properties of selected underutilized yams and

development of cupcakes using "Raja ala" (Diascorea alata) flour" at the third international research symposium on pure and applied sciences organized by University of Kelaniya, Sri Lanka. And also she was being a co-author for a paper titled, "Development of tea concentrate to incorporate in bubble tea using refused black tea and assessment of sensory properties and phytochemical composition" in the International Journal of Food science and Nutrition



Prof. I. Wickramasinghe is a Professor attached to the Department of Food Science and Technology, University of Sri Jayewardenepura. She has been engaged with research on post-harvest technology tea flavonoids and other herbal compounds of biological significance and the author of over 100 indexed, peer reviewed national and international research publications covering different fields of Food Science and Technology. She holds patents deriving from her research.



Dr. (Mrs.) M.A. Dulani Somendrika is a senior lecturer attached to Department of Food Science and Technology, University of Sri Jayewardenepura. She has been engaged with research on roots and tuber crops processing, cleaner production and life cycle assessment.