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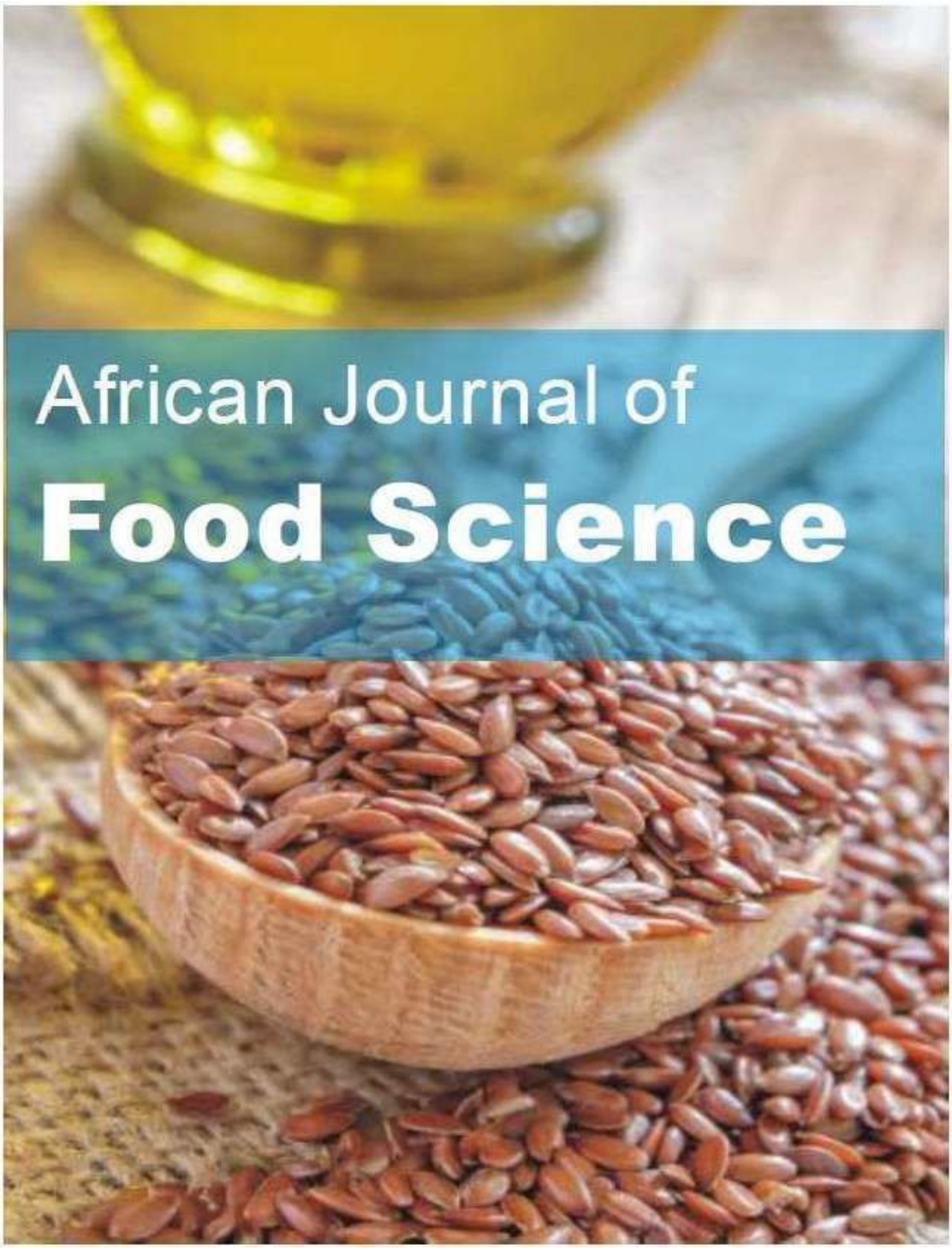

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African Journal of Food Science

Full Length Research Paper

Effect of endosperm maturity on the physicochemical composition and sensory acceptability of coconut (*Coco nucifera*) milk and yoghurt

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The effect of endosperm maturity on the physicochemical compositions and sensory acceptability of coconut milk and yogurt was studied. The influence of fermentation time on the physicochemical characteristics and sensory acceptability of coconut yogurt was also determined. Varied coconut endosperm maturity (soft, medium and hard) and fermentation time (6, 12, 18 and 24 h) were used to produce milk and yogurt. The physicochemical compositions and sensory acceptability of the samples were evaluated using standard methods. The physicochemical characteristics of coconut milk and yogurt were influenced by both endosperm maturity and fermentation time. Coconut milk produced from hard coconut endosperm was the most preferred and recorded the highest brix (3.31°), fat (6.71%), total solid (16.02%), and acidity (1.26%) levels. Coconut yogurt fermented for 6 h was the most preferred. Optimization of both coconut milk and yogurt processes could produce a commercially viable product.

Key words: Coconut milk, coconut yoghurt, fermentation, physicochemical, sensory.

INTRODUCTION

Consumers are increasingly becoming aware of their health needs, as such there is a growing demand for plant-based milk and milk products, such as yogurt. People with dairy allergies and sensitivities, as well as those who have concerns about the use of animal products, including vegans, are turning to plant-based milk alternatives (Zandona et al., 2021).

In Ghana, where most adults are lactose intolerant, there is a rising demand for plant-based alternatives that are promised to be lactose-free, cholesterol-free, devoid of dairy proteins, trans fats, and low in calories (Storhaug et al., 2017). Plant-based milk and milk products are typically based on cereals or pseudocereals, legumes, seeds, or nuts, either produced individually or sometimes as composites (Sethi et al., 2016; Mäkinen et al., 2016). The main commodities used include soy, groundnut, tiger nut, almond, rice, and coconut milk (Vanga and Raghavan, 2018; Astolfi et al., 2020).

These plant-based milks are promoted as functional foods to health-conscious consumers due to their

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superior bioactive compounds such as phenolic compounds, antioxidants, dietary fiber, medium-chain fatty acids, phytosterols, and isoflavones (Zandona et al., 2021). Plant-based milks are produced using unit processes, such as the disruption of the plant milk source through size reduction processes, milk extraction, formulation, and packaging (Tangyu et al., 2019). The milk only requires inoculation with mono or mixed cultures at a suitable temperature and is allowed to ferment to produce curd or yogurt (Tangyu et al., 2019). Plant-based milk and milk products have been marketed based on claims of naturalness and sustainability (Schiano et al., 2020). However, research has indicated that most plant-based milk and milk products are classified as processed or ultra-processed foods according to the NOVA classification (Astolfi et al., 2020; Braesco et al., 2022). These processed and ultra-processed foods contain synthetic ingredients such as additives (Braesco et al., 2022). This categorization of plant-based milk and milk products may deter consumers seeking minimally processed food products with clean labels. Production of plant-based milk and yogurt using minimal processing technologies would not only meet consumers' needs but would also be vital for ease of technology transfer to the artisanal food industry.

Coconut milk is regarded as a functional food due to its high fiber and oil contents, as well as its nutritional benefits (Paul et al., 2020). The oil has been associated with a range of health advantages, including increased insulin secretion, the utilization of blood glucose, and anti-inflammatory effects (Dhanasekara et al., 2022). It is high in calcium, potassium, phosphorus, and the vitamins B6, C, and E (Tulashie et al., 2022). Although it has high saturated fat, it is considered a good plant milk source due to its good digestibility (Chetachukwu et al., 2019). Additional probiotic health benefits are gained when the milk is used to make yogurt. Yogurt is a nutrient-dense functional food created through lactic acid fermentation, and it has traditionally played an important role in the range of fermented food products that contribute to good health and well-being (Mostafai et al., 2019). The probiotic qualities of yogurt allow it to be used for a variety of medical purposes, including the treatment of gastrointestinal diseases, the prevention of antibiotic-induced diarrhea, and the alleviation of vitamin D insufficiency in hyperlipidemic individuals (Imele and Atemnkeng, 2001; Mostafai et al., 2019). Ghana is the top producer of coconuts in the West African sub-region, with an annual production of over 400,000 tons as of the year 2020 (FAOSTAT, 2023). However, the crop is largely underutilized, as its commercial use is primarily for oil production. There have been other food applications at the artisanal level, such as the production of toffees, cookies, and chips. It is important to take advantage of the use of coconut for milk and yogurt production as a means of diversifying the commodity and improving its utilization. Coconuts are harvested at different maturity levels in Ghana.

Consumers who are primarily interested in coconut water often discard the endosperm, which varies in maturity. These endosperms include soft coconut endosperm, medium coconut endosperm, and hard coconut endosperm (Angeles et al., 2021). Soft endosperms are typically found in young coconuts, usually about 6 months old, while medium endosperms are at the middle stage of coconut development, and hard endosperms are obtained from matured coconuts (Angeles et al., 2021). The aim of this study was to evaluate the effect of coconut maturity (thickness) on the physicochemical properties and sensory acceptability of coconut milk and coconut yogurt. The study also sought to determine the effect of fermentation time on the physicochemical properties and sensory acceptability of coconut yogurt.

MATERIALS AND METHODS

Sources of raw materials

Fresh coconut, starter culture, and sugar used for the study were all procured from a local market in Kumasi. The starter culture contained *Lactobacillus bulgaricus, Streptococcus thermophilus,* and *Lactobacillus acidophilus.*

Experimental design

The research employed a 3 × 4 factorial experimental design, with Factor I being coconut endosperm thickness at 3 levels (soft, medium and hard endosperm) and Factor II being fermentation time at 4 levels (6, 12, 18 and 24 h).

Vernier Caliper was used to measure the thickness of the pulp (soft endosperm with an average thickness of 4 mm, medium endosperm: an average thickness of 10.5 mm and hard endosperm: an average thickness of 15.3 mm).

Processing of coconut milk

The coconut was washed, de-husked, and gently cracked open into halves. The coconut endosperm was removed and carefully washed. The washed endosperms were cut into pieces and blended (using a Binatone Heavy Duty Commercial Blender BL-1505) with warm water (50°C) to dissolve the fat in the shredded coconut pulp. For 1 kg of coconut endosperm, 1 L of warm water was used. The slurry was sieved with a cheese cloth, bottled, and cooled for sensory and physicochemical analyses. Figure 1 shows the process flow diagram for coconut milk.

Preparation coconut yoghurt

Coconut milk samples were pasteurized at a temperature range of 85 to 90°C for 20 min and then cooled rapidly to 45°C for inoculation with a 2% starter culture (yogourmet). The mixture was incubated at 45°C for 6, 12, 18 and 24 h to obtain different coconut yoghurt samples. The set yogurt was quickly cooled for sensory evaluation and other physicochemical analyses. Figure 2 shows the process flow diagram for coconut yoghurt.

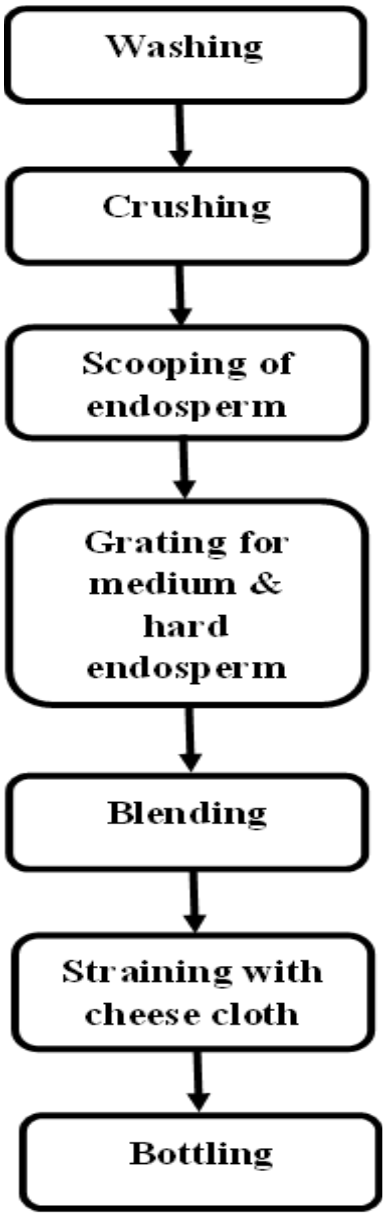

Figure 1. Process flow diagram for coconut milk.

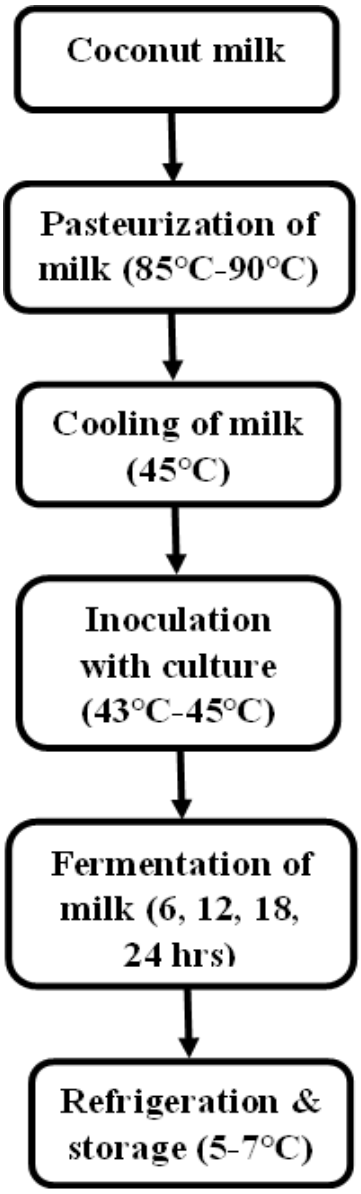

Figure 2. Process flow diagram for coconut yoghurt.

Physicochemical analysis of coconut milk and yoghurt

The titratable acidity of the samples was determined by using the method by AOAC (2000). A weighed amount of sample (5 g) was titrated against a standard 0.5 N NaOH to a pink endpoint using phenolphthalein as an indicator. The acid factor is 90.01 for lactic acid which is the dominant acid in milk (AOAC, 2000). The total titratable acidity value was calculated using the following formula:

$$Titratable\ acidity\ (\%) = \frac{Titre \times Normality\ of\ titrant \times 90.01 \times 100}{Weight\ of\ sample \times 1000} \quad (1)$$

The fat content of the coconut milk and yoghurt was determined by the Soxhlet extraction method with the aid of petroleum ether as extraction solvent (AOAC, 2000). The crude protein content of both the coconut milk and the yoghurt was determined using the Kjeldahl technique (AOAC, 2000).

The total ash was determined by the dry ashing method (AOAC, 2000), which involved weighing 2 g of the yoghurt samples into porcelain crucibles and incinerating the samples for 2 h in a muffle furnace (Thermolyne Benchtop Muffle furnace F48025-60, ThermoFisher Scientific) preheated at 600°C.

The moisture content of the sample was determined using a thermostatically controlled oven (Carbolite, PN 60 with 301 controller option) at 100 for 24 h based on the AOAC technique (AOAC, 2000). The following formula was used to derive the moisture percentage.

$$\%\ \text{moisture} = W_1 - \frac{W_2 \times 100}{W_1} \quad (2)$$

where W_1=initial weight of sample; W_2=weight of the dried sample. A digital pH meter (Jenway 3505, UK) was used to determine the pH of the samples and readings recorded. The total solids were determined using the AOAC technique (AOAC, 2000). The proportion of total solids in the residue was determined as the difference of 100% and the percentage moisture content of the samples.

Sensory evaluation of coconut milk and yoghurt samples

Coconut milk and coconut yogurt samples were refrigerated at temperatures between 4 and 7°C in plastic containers and labeled with three-digit identifiers. Fifty consumer panelists were asked to rate the samples on a 9-point Hedonic scale (1-dislike extremely to 9, like extremely) based on appearance, color, aroma, flavor, mouthfeel, taste (sourness), aftertaste, and overall acceptability (Obi et al., 2010). Water was used as palate cleansers between samples.

Data analysis

SPSS (version 21) was used to analyze the data. The influence of coconut maturity and fermentation on the samples was determined using analysis of variance (ANOVA), and significant differences were considered at $p < 0.05$.

RESULTS AND DISCUSSION

Effect of coconut maturity on the physicochemical compositions of coconut milk

There was a general increase in brix sugar content of the milk samples with the maturity of the endosperm used. The brix sugar content ranged between 2.4 and 3.34° brix for milk produced from the soft endosperm and medium endosperm, respectively (Table 1). These values were lower than the average value of 5.0 reported for skim coconut milk (Jermwongruttanachai et al., 2021). Possible causes for this difference include dissimilarities in formulation and the variety of coconuts used. The brix levels for all the coconut milk samples were below the Codex standard limits of 6.6 to 12.6 for light coconut milk (CODEX STAN 240-2003). This implies that these milk samples may require some form of sweetening to attain the required brix levels or concentration of solids. According to Raissa et al. (2007), the concentration of brix sugars in coconut milk continuously increases in the early months of development and then progressively diminishes at the stage of complete maturity of the nut, which is consistent with the results of this study. The fat content of the milk also increased with endosperm maturity, as observed by Angeles et al. (2021). Milk produced from hard coconut endosperm recorded the highest fat content of 6.71%, while milk produced from soft coconut endosperm recorded the lowest fat content of 2.33%. According to the Codex Standard, the fat content for light coconut milk and normal coconut milk is 5.0 and 10.0%, respectively. Therefore, the samples obtained from the study can be considered light coconut milk.

The protein content of the milk sample produced from soft coconut endosperm was the highest with a value of 3.48%. On the other hand, the moisture content decreased with increasing coconut maturity, ranging from 90.72% (for milk produced from soft endosperm) to 83.98% (for milk produced from hard endosperm). (Table 1). The moisture content of the milk was comparable to the Codex standard of 87.3 and 93.40% for normal and light coconut milk, respectively (CODEX STAN 240-2003). The titrable acidity for the milk sample produced from hard coconut endosperm was the highest with a value of 1.26%, while the soft coconut endosperm content was 0.44%. The predominant acids that may be present in coconut milk are lauric, myristic, and palmitic acids, which increase with coconut maturity (Lira et al., 2017).

The total solids of the coconut milk samples increased with the thickness of the endosperms, ranging from 9.28 to 16.02% for milk produced from coconut milk with soft and hard endosperm, respectively. There was no statistically significant difference ($p > 0.05$) in the pH of the milk samples, which ranged between 3.5 and 4.06, respectively. The pH of the milk samples indicates that it is slightly acidic compared to the required Codex standard of 5.95 (CODEX STAN 240-2003).

Effect of coconut maturity on the physicochemical composition of coconut yoghurt

Results indicate that there is a statistically significant difference ($p < 0.05$) in the brix levels of coconut yogurt samples. Yogurt produced from soft coconut endosperm recorded the highest brix of 2.52° brix, compared to the other two samples, which both recorded 2.18° brix. The fat contents of the yogurt samples ranged from 2.39 to 7.74% for yogurt samples produced from soft and hard endosperm, respectively (Table 2). The fat content of the coconut increased with endosperm maturity. According to Codex standards, the fat content of yogurt should be less than 15%, and the samples obtained were less than 15%, hence the result meets Codex's requirements. The fat content of the product will influence its body and mouthfeel.

The moisture content of the yogurt samples also decreased with the maturity of the coconut used, ranging between 82.90% for yogurt produced from hard coconut and 90.7% for yogurt produced from soft coconut, respectively. The protein content of the yogurt samples ranged between 2.0 and 2.6%. These values are slightly lower than the required value of 2.7% (CODEX STAN 240-2003). The titratable acidity content of the coconut yogurt sample produced from soft coconut yogurt recorded the highest value of 1.24%, while the hard

Table 1. Physicochemical compositions of coconut milk from varying endosperm thickness.

Parameter	Mean (± SEM) of type of coconut used			P-value
	Hard coconut endosperm	Medium coconut endosperm	Soft coconut endosperm	
Brix sugar	3.31 ± 0.28[a]	3.34 ± 0.11[a]	2.48 ± 0.23[b]	0.028
Fat (%)	6.71 ± 1.17[a]	4.88 ± 1.01[b]	2.33 ± 0.09[c]	0.014
Protein (%)	2.14 ± 0.52[b]	1.74 ± 0.41[c]	3.48 ± 0.51[a]	0.020
Moisture	83.98 ± 0.64[c]	85.85 ± 0.65[b]	90.72 ± 0.26[a]	<.001
Titratable acidity	1.26 ± 0.25[a]	1.17 ± 0.24[a]	0.44 ± 0.25[b]	0.017
Total solids	16.02 ± 0.90[b]	14.15 ± 0.82[b]	9.28 ± 0.60[a]	0.008
pH	4.06 ± 0.48	3.50 ± 0.23	3.98 ± 0.28	0.008

Means bearing different superscripts in the same row are significantly different (P<0.05). S.E.M = Standard error of means.

Table 2. Physicochemical compositions of coconut yogurt form varying endosperm thickness.

Parameter	Mean (± SEM) of type of coconut used			P-value
	Hard coconut endosperm	Medium coconut endosperm	Soft coconut endosperm	
Brix sugar	2.18 ± 0.01[b]	2.18 ± 0.02[b]	2.52 ± 0.11[a]	0.001
Fat (%)	7.74 ± 0.09[a]	4.64 ± 0.11[b]	2.39 ± 0.08[c]	0.001
Moisture (%)	82.99 ± 0.05[c]	85.60 ± 0.07[b]	90.77 ± 0.25[a]	0.001
Protein (%)	2.00 ± 0.01[a]	2.30 ± 0.11[a]	2.61 ± 0.23[a]	0.001
Titratable acidity (%)	1.07 ± 0.01[c]	1.15 ± 0.01[b]	1.24 ± 0.01[a]	0.001
Total solids	17.1 ± 0.08[c]	14.4 ± 0.09[b]	9.35 ± 0.09[a]	0.001
pH	4.08 ± 0.08[a]	4.03 ± 0.09[a]	3.94 ± 0.08[a]	0.539

Means bearing different superscripts in the same row are significantly different (P<0.05). S.E.M = Standard error of means.

coconut yogurt produced recorded the lowest value of 1.07%.

The titratable acidity level was marginally comparable to the Codex standard for yogurt (0.6%), but comparable to the total acidity of coconut yogurt reported by Peters et al. (2023), which ranged between 0.352 and 2.079%. This means that these yogurt samples may be slightly sour. However, a slight increase in the brix by sweetening could yield a brix-to-acidity ratio that offers favorable organoleptic properties.

There was a significant difference in the total solids content of the coconut yogurt samples. Yogurt samples produced from hard coconut endosperm recorded the highest total solids content (17.01%), while the soft coconut yogurt had the lowest (9.23%). The total solids content of the yogurt is indicative of its thickness, which is an important quality indicator.

The pH of the yogurt samples ranged between 3.94 (for yogurt produced from soft coconut endosperm) and 4.08 (for yogurt produced from hard coconut endosperm). Studies by Peters et al. (2023) also recorded slightly different values, ranging from 3.78 to 3.81, which may be due to the blend of cow milk and coconut milk used in their study.

Effect of fermentation time on physicochemical composition of coconut yoghurt

Results indicate that the fermentation time significantly affected the brix sugar, fat, total solid, protein, and titratable acidity ($p < 0.05$); however, changes in total solids and pH were not statistically significant ($p > 0.05$) (Table 3). The brix sugar decreased with increasing fermentation time, ranging from 2.55° brix for yogurt fermented for 6 h to 2.1° brix for coconut yogurt fermented for 24 h. The fat content of the yogurt samples also increased with fermentation time (Table 3).The increase in fat content of the samples during fermentation could be associated with an increasing microbial mass during fermentation. This increase in microbial mass results in increasing solids, which contributes to the decrease in moisture and an increase in protein contents of the samples during fermentation. As the sugar substrates are converted to acids over time during fermentation, it is expected that the acidity of the yogurt sample will increase with the time of fermentation. This phenomenon is consistent with the results obtained, where yogurt fermented for 6 h recorded a titratable acidity of 1.08%, which increased to 1.24% after 24 h of

Table 3. Physicochemical compositions of coconut yogurt at varying fermentation time.

Parameter	6 h	12 h	18 h	24 h	P-value
Brix sugar (%)	2.55±0.01^{a}	2.33±0.01^{b}	2.21±0.01^{c}	2.10±0.01^{d}	0.001
Fat (%)	4.53±0.01^{b}	4.61±0.01^{b}	5.22±0.01^{a}	5.34±0.01^{a}	0.001
Moisture	86.70±0.06^{a}	86.70±0.06 ^{a}	86.20±0.06^{a}	86.22±0.06^{a}	0.100
Protein (%)	1.27±0.02^{a}	1.27±0.02^{a}	1.40±0.02^{b}	1.28±0.02^{a}	0.001
Titratable acidity (%)	1.08±0.01^{c}	1.13±0.01^{b}	1.14±0.01^{b}	1.26±0.01^{a}	0.001
Total solids	13.30±0.0^{a}	13.30±0.01^{a}	13.80±0.01^{a}	13.78±0.01	0.101
pH	4.06±0.10^{a}	4.04±0.10a	4.02±0.10 ^{a}	3.96±0.10 ^{a}	0.909

Means bearing different superscripts in the same row are significantly different (P<0.05);S.E.M = Standard error of means.

Table 4. Mean sensory score of coconut milk from different endosperm thickness.

Attributes	Soft coconut endosperm	Medium coconut endosperm	Hard coconut endosperm	P-value
Appearance	6.37±1.14^{b}	6.05±1.07^{b}	7.09±1.01^{a}	0.003
Color	6.92±1.28^{c}	6.52±1.30^{a}	7.09±1.25^{b}	0.000
Aroma	5.92±1.03^{c}	5.37±1.20^{a}	7.02±1.28^{b}	0.000
Flavor	5.94±1.05^{c}	5.31±1.01^{a}	7.00±1.59^{b}	0.000
Mouth feel (Body)	5.60±1.14^{c}	4.72±1.28^{a}	7.27±1.45^{b}	0.000
Taste	5.27±1.04^{c}	4.82±1.23^{a}	6.64±1.07^{b}	0.000
After taste	5.74±1.07^{c}	4.64±1.20^{a}	7.37±1.58^{b}	0.000
Overall acceptability	5.92±1.25^{c}	4.81±1.30^{a}	7.56±1.54^{b}	0.000

Scale 1- dislike extremely to 9- like extremely.

fermentation. The increase in acidity with an increase in fermentation time will have acceptability implications. A good balance of brix and acidity is required to produce an acceptable product.

Sensory acceptability of coconut milk samples

There was a statistically significant difference ($p<0.05$) in the sensory attributes of all the coconut milk samples evaluated. The sensory acceptability of the milk samples improved with increasing coconut maturity. Coconut milk produced from hard endosperm was most preferred for appearance (7.09), color (7.09), flavor (7.00), taste (6.64), aftertaste (7.37), mouthfeel (7.27), and overall acceptability (7.56) (Table 4). Poongodi and Rameshkumar (2022) found a mean value of 7.1 for the aroma of coconut milk and a value of 6.57 for the mean color of coconut milk, which is consistent with the results of this study. Products made from soft and medium coconut endosperm were barely acceptable. The acceptability of hard coconut milk was the best of the three samples. This means that the acceptability of the coconut milk will improve with increasing solid content, as improved solids will enhance the taste, a very important purchasing indicator. Thus, the best endosperm for coconut milk production is the hard coconut. However, further studies can be conducted on producing coconut milk from a combination of endosperms of various thicknesses to ascertain its sensory acceptability.

Sensory acceptability of coconut yoghurt samples

The preferences of the panelists significantly varied ($p < 0.05$) among all attributes evaluated in all the yogurt samples. The acceptability of coconut yogurt samples reduced with increasing fermentation time (Table 5). When compared with others fermented for 12, 18, and 24 h, coconut yogurt fermented for 6 h was the most preferred for all attributes (appearance, color, aroma, flavor, mouthfeel, taste, and aftertaste). This was reflected in the general acceptance of coconut yogurt, with coconut fermented for 6 h being the most preferred. The aroma, taste, and texture of yogurt are influenced by fermentation period and temperature. Prolonged fermentation increases the acidity of yogurt, which affects its sensory properties. Table 5 shows the mean sensory attributes of coconut yoghurt samples.

Conclusion

Coconut maturity influences parameters such as fat

Table 5. Mean sensory score of coconut yogurt at different fermentation times.

Attributes	Sample Codes				P-value
	100A	100B	100C	100D	
Appearance	7.52±1.20^{c}	6.98±1.32^{b}	6.38±1.25^{b}	6.04±1.54^{a}	0.000
Color	7.46±1.34^{c}	7.14±1.55^{c}	6.64±1.34^{b}	6.22±1.42^{a}	0.003
Aroma	7.54±1.28^{c}	6.84±1.43^{b}	6.40±1.22^{b}	5.70±1.51^{a}	0.005
Flavor	7.68±1.42^{b}	7.16±1.54^{b}	6.38±1.33^{a}	5.68±1.23^{a}	0.006
Mouth-feel	7.16±1.34^{c}	6.92±1.04^{c}	6.44±±1.36^{b}	5.32±1.26^{a}	0.000
Taste (sourness)	7.40±1.22^{c}	6.86±1.38^{bc}	6.26±1.52^{b}	5.08±1.45^{a}	0.005
After taste	7.80±1.44^{c}	7.10±1.34^{c}	6.28±1.41^{b}	5.24±1.04^{a}	0.001
Overall acceptability	7.98±1.33^{d}	7.34±1.56^{c}	6.70±1.46^{b}	5.62±1.33^{a}	0.000

100A = Coconut yoghurt for 6 h fermentation, 100B = Coconut yoghurt for 12 h fermentation, 100C = Coconut yoghurt for 18 h fermentation, 100D = Coconut yoghurt for 24 h fermentation.

content, total solids content, pH, and brix of both coconut milk and yogurt. The acceptability of coconut milk increases with endosperm maturity. Hence, coconut milk produced from mature coconuts with hard endosperm will be a commercially viable choice. However, a careful blend of endosperm from soft, medium, and hard coconuts could yield milk with desirable organoleptic characteristics. In the production of coconut yogurt, parameters such as brix, titratable acidity, fat, and protein are significantly influenced by fermentation time. Fermentation time also influences coconut yogurt acceptability. At an incubation temperature of 45°C, coconut milk should be incubated for a maximum of 6 hours to produce acceptable coconut yogurt.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Angeles JGC, Lado JP, Pascual ED, Laurena A.C, Laude RP (2021). Epigenetic Considerations on Altered Phenotypes of the Coconut Endosperm. The Coconut Genome pp. 175-190.

Association of Official Analytical Chemists (AOAC) (2000). Official Methods of Analysis. 17th ed Washington DC USA.

Astolfi ML, Marconi E, Protano C, Canepari S (2020). Comparative elemental analysis of dairy milk and plant-based milk alternatives. Food Control 116:107-327.

Braesco V, Souchon I, Sauvant P, Haurogné T, Maillot M, Féart C, Darmon N (2022). Ultra-processed foods: how functional is the NOVA system?. European Journal of Clinical Nutrition 76(9):1245-1253.

Chetachukwu AS, Thongraung C, Yupanqui CT (2019). Development of reduced-fat coconut yoghurt: Physicochemical, rheological, microstructural and sensory properties. International Journal of Dairy Technology 72(4):524-535.

CODEX STAN (240-2003). Available at: https://coconuthandbook.tetrapak.com/chapter/chemistry-coconut-milk-and-cream

Dhanasekara CS, Nelson A, Spradley M, Wynn A, Robohm-Leavitt C, Shen CL, Kahathuduwa CN (2022). Effects of consumption of coconut oil or coconut on glycemic control and insulin sensitivity: A systematic review and meta-analysis of interventional trials. Nutrition, Metabolism and Cardiovascular Diseases 32(1):53-68.

FAOSTAT (2023). https://www.fao.org/faostat/en/%3f#home

Imele H, Atemnkeng A (2001). Preliminary study of the utilization of coconut in yoghurt production. Journal of Food Technology 6:121-125.

Jermwongruttanachai P, Pathaveerat S, Noypitak S (2021). Effect of temperature denaturation of skimmed coconut to produce a new product, Coconut water. Journal of Food Processing and Preservation 45(12):e16046.

Lira GM, Cabral CCVQ, de Oliveira ÍBA, Figueiredo BC, Simon SJGB, Bragagnolo N (2017). Changes in the lipid fraction of king mackerel pan fried in coconut oil and cooked in coconut milk. Food Research International 101:198-202.

Mäkinen OE, Wanhalinna V, Zannini E, Arendt EK (2016). Foods for special dietary needs: Non-dairy plant-based milk substitutes and fermented dairy-type products. Critical Reviews in Food Science and Nutrition 56(3):339-349.

Mostafai R, Nachvakc SM, Mohammadi R, Rocha RS, da Silva MC, Esmerino EA, Mortazavian AM (2019). Effects of vitamin D-fortified yogurt in comparison to oral vitamin D supplement on hyperlipidemia in pre-diabetic patients: a randomized clinical trial. Journal of Functional Foods 52:116-120.

Obi TE, Henshaw FO, Atanda OO (2010). Quality evaluation of plain-stirred probiotic yoghurt produced from skim and whole milk powder during refrigerated storage. Electronic Journal of Environmental, Agricultural and Food Chemistry 9(7).

Paul AA., Kumar S, Kumar V, Sharma R (2020). Milk Analog: Plant based alternatives to conventional milk, production, potential and health concerns. Critical Reviews in Food Science and Nutrition 60(18):3005-3023.

Peters OO, Afolabi MO, Makinde FM (2023). Chemical, physicochemical and sensory properties of yoghurt and yoghurt simulates produced from the blends of cow milk and coconut milk. In IOP Conference Series: Earth and Environmental Science 1219(1):012020. IOP Publishing.

Poongodi VS, Rameshkumar S (2022). Development and formulation for the manufacturing of coconut milk shrikhand. International Journal of Engineering Technology and Management Sciences 6(5):1-7.

Raissa ET, Felicito M, Rodriguez RPL, Marni EC (2007). Total Free Sugars, Oil and Total Phenolics Content of Stored Coconut (*Cocos nucifera* L.) Water. Philippine Journal of Science 136(2):103-108.

Schiano AN, Harwood WS, Gerard PD, Drake MA (2020). Consumer perception of the sustainability of dairy products and plant-based dairy alternatives. Journal of Dairy Science 103(12):11228-11243.

Sethi S, Tyagi SK, Anurag RK (2016). Plant-based milk alternatives an emerging segment of functional beverages: a review. Journal of Food Science and Technology 53:3408-3423.

Storhaug CL, Fosse SK, Fadnes LT (2017). Country, regional, and global estimates for lactose malabsorption in adults: a systematic review and meta-analysis. The Lancet Gastroenterology and Hepatology 2(10):738-746.

Tangyu M, Muller J, Bolten CJ, Wittmann C (2019). Fermentation of

plant-based milk alternatives for improved flavour and nutritional value. Applied Microbiology and Biotechnology 103:9263-9275.
Tulashie SK , Amenakpor J, Atisey S, Odai R, Akpari EEA (2022). Production of coconut milk: A sustainable alternative plant-based milk. Case Studies in Chemical and Environmental Engineering 6:100206.
Vanga SK, Raghavan V (2018). How well do plant based alternatives fare nutritionally compared to cow's milk? Journal of Food Science and Technology 55(1):10-20.
Zandona L, Lima C, Lannes S (2021). Plant-based milk substitutes: factors to lead to its use and benefits to human health. Milk Substitutes-Selected Aspects 1:1-16.

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Physico-chemical, functional and anti-nutritional properties of taro (*Colocasia esculenta*) flour as affected by cooking and drying methods

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The effects of cooking medium, cooking time, and drying conditions on the physicochemical, functional, pasting, and anti-nutritional properties of taro flour were studied. Physicochemical and functional characteristics indicated that flour from taro slices cooked in water had higher L*, WAI, and OAC, and intermediate WSI, a*, and b* values. Acidic cooking treatment significantly decreased the oxalate and phytate content of taro flour. Microwave power levels negatively affected the emulsifying and foaming power of the flour. Cooking time had a positive significant effect on WAC and a negative effect on OAC, emulsion, and foaming capacity of the flour ($p < 0.05$). The score plot of PCA showed that flours from lemon-cooked taro slices had a large negative score, while steam-cooked slices' flours had a large positive score in PC1, and water-cooked slices' flours lie near the center axis of the score plot. The flours from water and steam-cooked taro slices showed higher values of physicochemical and functional properties, whereas flours from lemon-cooked taro slices were higher in L* value of color and pasting properties. Oxalate and phytate content were low in the flours from lemon solution-cooked taro slices.

Key words: Taro flour, cooking conditions, microwave drying, functional, anti-nutritional properties.

INTRODUCTION

Taro (*Colocasia esculenta*) is an important food staple in developing countries in Africa, the West Indies, the Pacific region, and Asia. Tubers are grown worldwide in hot and humid regions. Taro belongs to the Arum family (Araceae), genus *Colocasia*, and is a tropical tuber crop primarily cultivated for its underground corms, mainly consumed in tropical areas of the world. Taro corms are rich in gums (mucilage) and contain 70 to 80% (db) starch with small granules. Nutritionally, taro offers a broader complement of vitamins and nutrients compared to other tubers. Taro corms contain a considerable amount of starch and protein. Additionally, it is a rich source of calcium, phosphorus, iron, vitamin C, thiamine, riboflavin, and niacin. Despite its nutritional, industrial,

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and health importance, taro has not received sufficient research attention to enhance its potential. Moreover, it experiences higher post-harvest losses, nearly 30%, primarily due to its high moisture content (Kaushal et al., 2013).

Acridity of taro is another important factor which limits their consumption. Raw taro corms contain a considerable amount of ethanedioic acid (oxalic acid) ($H_2C_2O_4$) in forms of soluble oxalic acid and insoluble oxalate salts. Soluble oxalic acid can form complexes with calcium, magnesium, or potassium, and hence reduces mineral availability in the diet. Continuing consumption of taro with a high oxalate salt content can lead to gallstone deposition in the gall-bladder. Boiling of taro corms and steeping in water for 24 h can reduce the oxalates substantially. Bradbury and Holloway (1988) suggested that the crystals have to interact with a certain chemical on the raphide surface before acridity is experienced. The acridity factor of taro can be reduced by peeling, grating, soaking and fermentation operations during processing (Kaushal et al., 2013).

In order to minimize tuber losses and enhance their utility in various processed food products, they must be converted from perishable to non-perishable form through suitable processing technique. Taro chips or crisps (Emmanuel-Ikpemeet al., 2007; Kumar et al., 2015a, 2017a) are the most popular commodities prepared using taro corms directly, while majority of the taro-based products are prepared using taro flour. Bread (Ammar et al., 2009; Arıcı et al., 2020), cookies (Tekle, 2009; Giri and Sanjeev, 2020), biscuits (Himeda et al., 2014; Wheat, 2019), cakes (Kumar et al., 2015b), noodles (Kaushal and Sharma, 2014) and taro-based extruded snacks (Bhattacharyya et al., 2006; Rodríguez et al., 2011) have been prominently popular food products prepared using taro flour. Moreover, conversion of raw taro into flour can be achieved by drying of taro slices using various methods like sun drying (Soudy et al., 2014), solar drying (Njintang et al., 2010), hot air drying (Kaushal et al., 2012), tray drying (Kumar et al., 2017b), and freeze drying (Hung and Duy, 2012) followed by milling of these dried slices into flour.

Besides these drying methods, microwave drying is gaining importance as an alternative drying method for a wide variety of fruits and vegetables. Microwave system for drying is based on the conversion of alternating electromagnetic field energy into thermal energy by moving the polar molecules of a fruit/vegetable (Workneh et al., 2011). It is rapid and economical technique to reduce the moisture content of materials. Although several reports are available in literature on the preparation and characterization of taro flour but no report exists on the taro flour prepared from the taro slices cooked in different medium followed by microwave drying. Therefore, the objectives of this study were to investigate the effect of cooking conditions and microwave drying power on the proximate composition physico-chemical, functional, and anti-nutritional properties of taro flour.

MATERIALS AND METHODS

Raw taro corms (commercial variety) were purchased from local market of Kanpur, Uttar Pradesh, India. Taro corms were thoroughly examined to ensure that they are disease resistant, fresh besides having high sustainability based on their physical attributes for prolonged usage in fabricating taro flour. Corms were thoroughly washed in clean water and kept at refrigerated temperature (8±1°C) until required for use.

Cooking conditions and drying treatments of taro slices

To study the effect of cooking conditions on properties of taro flour, fresh washed taro corms were mechanically cut into 5 mm thick slices using a vegetable slicer (Narang Corporation, Delhi, India) with an adjustment of ±0.1 mm. These slices were cooked separately in three different cooking medium namely water, steam, and lemon solution. The cleaned taro slices were divided into nine lots. Three lots were cooked in water for the periods of 5, 10 and 15 min, respectively. Next three lots were placed on the three staged round perforated stand. The stand was put in the pressure cooker (Hawkins cookers Ltd., Mumbai, India) and steam treatment was given without whistle for a period of 5, 10 and 15 min. Remaining three lots were cooked in lemon solution (pH=3.5±0.05) for the period of 5, 10 and 15 min, respectively. The cooked slices were dried in microwave oven (Model no 767W, LG India) at different power levels of 360, 540 and 720 W for a period of 24, 15 and 11 min, respectively. The dried slices were ground and converted into flour to pass through a 100 mesh sieve. The flours were packed into airtight sealed plastic bags and stored in a refrigerator for further quality analysis. A schematic diagram for preparation of taro flour by different cooking treatment and microwave power level is as shown in Figure 1.

Proximate composition of taro flours

The moisture content of the flour samples was determined by drying the sample in an oven at 105°C till constant weight (AOAC, 2005). Protein content was estimated from nitrogen content (N×6.25) obtained using Kjeldahl method by AOAC (2005). Fat content were determined by automatic Soxhlet unit (SOCS PLUS, Pellican equipment, Chennai) using ether as solvent according to the method of AOAC (2005). Ash content was determined by incinerating flour (3.0 g) in a muffle furnace at 550°C for 6 h, then weighing the residue after cooling to room temperature in a desiccator (AOAC, 2005). The crude fibre content was determined by standard method (AOAC, 2005) whereas the carbohydrate content was determined as, % carbohydrate = 100 - (% moisture + % protein + % fat + % fibre + % ash).

Physico-chemical properties of taro flour

The color of flour samples was determined in terms of L*, a*, and b* values by using Hunter Lab Ruston, VA (model no 45/0), Ruston, VA, USA). The instrument was calibrated against a standard white tile plate (L = 96.98, a = 0.03, b = 1.84) and black ceramic plate. A glass cell containing flour was placed above the light source, covered with black plate and L*, a* and b* color values were recorded. Bulk density (BD), water absorption index (WAI) and water solubility index (WSI) were determined by the method

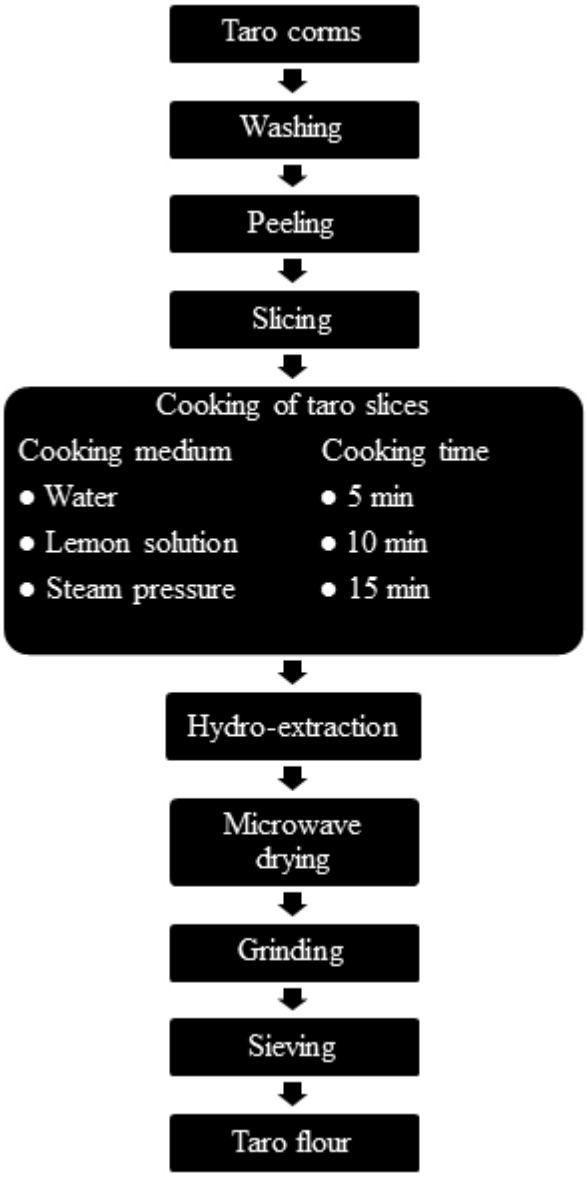

Figure 1. Schematic diagram for preparation of taro flours.

suggested by Kaushal et al. (2012). The blue value index (BVI) was determined by a method adapted from Njintang and Mbofung (2006).

Functional properties of taro flours

Water absorption capacity (WAC) and oil absorption capacity (OAC) of different flours were measured by the centrifugation method as suggested by Chandra et al. (2015). Emulsifying activity (EA) and emulsion stability (ES) were determined as described by Naczk et al. (1985). Foaming capacity (FC) was determined according to the method of Lin et al. (1974).

Pasting properties of the flour samples were studied using Rapid Visco Analyzer (Newport Scientific Pvt. Ltd, Australia). Viscosity profiles of flours were recorded using flour suspensions (10%, w/w; 25 g distill water). The temperature-time conditions included a heating step from 50 to 95°C at 6°C min^{-1} (after equilibrium time of 1 min at 50°C, a holding phase at 95°C for 5 min. The cooling was carried out from 95 to 50°C at 6°C min^{-1} with a holding for 2 min at 50°C. Parameters recorded were peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown viscosity (BV), and setback viscosity (SV).

Anti-nutritional properties of taro flours

Oxalate content was determined by the titration method as used by Adegbaju et al. (2019). One gram of the sample was weighed into 100 ml conical flask where 75 ml of 3 N H_2SO_4 was added and stirred intermittently with a magnetic stirrer for 1 h. It was then filtered using Whatman No.1 filter paper. From the filtrate, 25 ml was taken and titrated while hot (80-90°C) against 0.1 N $KMnO_4$ solution until a faint pink color persisted for at least 30 s.

$$\text{OxalateContent (mg/100g)} = \frac{\text{VolumeofKMn O}_4 \times \text{Sampledilution} \times \text{NormalityofKMnO}_4 \times \text{Oxalicacidfactor} \times 100}{\text{Sampleweight} \times \text{Sampletakenfortitration}}$$

The phytic acid (or phytate) content was measured by the method of Wang et al. (1988). The ground sample, 2 g was extracted with 40 ml of 0.5 M HNO_3 for 2 h and then filtered. The solution, 1 ml was used for the total phosphorous determination. Ferric chloride was added to another 10 ml of solution and heated in boiling water for 75 min. After centrifugation at 12000 g for 15 min, the supernatant was used to determine the soluble phosphorous. Total and soluble phosphorous levels were determined by colorimeter using 0.05 M ammonium thio-cyanate and were estimated using a phosphorous standard curve. The difference between total and soluble phosphorous was insoluble phosphorous. The phytic acid content was calculated from the insoluble phosphorous; assuming 1 mol of phytic acid contains 6 mol of insoluble phosphorous.

Statistical analysis

The processing treatments and analyses were conducted in triplicates, and mean scores of the results were reported. Data were analyzed using one way ANOVA, and Duncan multiple range test was used to separate the means. Minitab Statistical software version 16 (Minitab Inc. State College PA, USA) was used to perform principal component analysis (PCA) and Pearson correlation coefficients (r) for determination of variation amongst the observed properties of taro flour samples.

RESULTS AND DISCUSSION

Principal component analysis (PCA) was used to visualize the variation in the properties among taro flour samples made from different treatments of taro slices. PCA is useful statistical technique to reduce the large number of variables to few variables in two axis, axis 1 called first principal component (PC1) and axis 2 called second principal component (PC2) that describe the greatest change in the data analyzed. PC1 and PC2 described the 58.9 and 22.3% of the variance respectively. Together, both PCs represented 81.2% of the total variability of the data. All flour samples from taro slices cooked in lemon solution and samples from water cooked taro slices except 5 min cooked and dried at 540 and 720W, were located at the left of the score plot, while flour samples prepared with steam pressure cooked

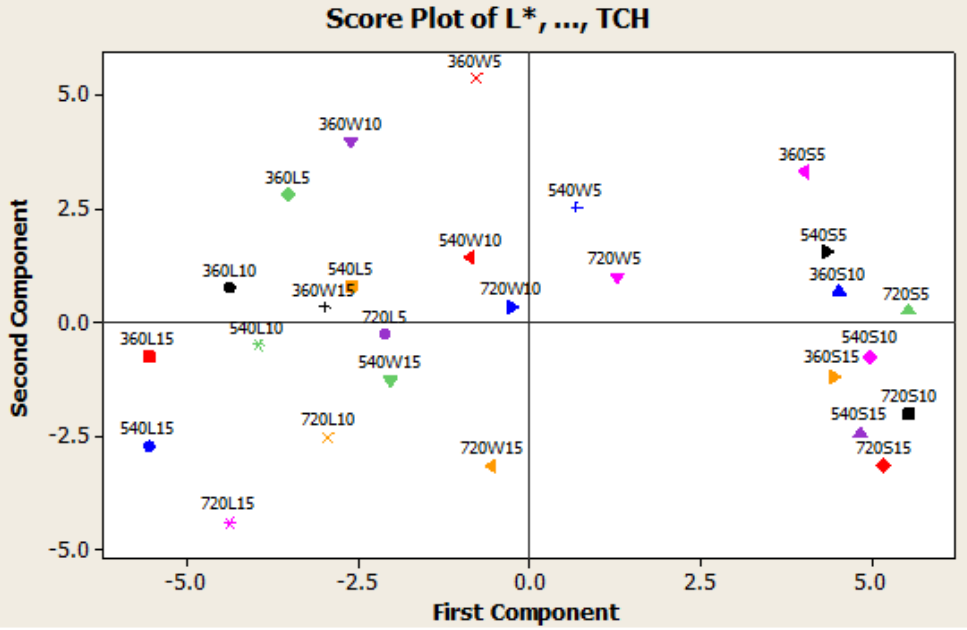

Figure 2. PCA score plot of PC1and PC2 describes the overall variation among different flours. First numeric value of the code of flours represents the microwave drying power, middle alphabet W, L, S represent cooking medium namely water, lemon solution and steam, last numeric value represent cooking time in min.

slices were located at the right of the score plot (Figure 2). Flour samples from taro slices cooked in lemon solution showed a large negative score; whereas flour samples from steam pressure cooked slices had a large positive score in PC1. Flour samples from water cooked taro slices lies near to the centre axis of the score plot. Irrespective of the cooking medium, the flour from 5 and 15 min cooked slices had positive and negative score, respectively in PC2. The loading plot of the two PCs showed the information about correlations among the measured properties (Figure 3). The properties of taro flour samples that are highly positively correlated indicated very close to each other and negatively correlated showed in opposite directions on the loading plot.

Proximate composition

Proximate composition of taro flour samples is shown in Table 1. Samples cooked in water and lemon solution showed the significant decrease in moisture, protein, fat, ash and fibre content, whereas carbohydrate content significantly increased with cooking time ($p<0.05$). The decrease may be due to the losses that occurred as a result of leaching out of the constituents during cooking. The results are in agreement with Amon et al. (2014), flour from boiled taro corms prepared in different boiling time. It was also observed that the decrease in the components was more in lemon solution cooked samples as compared to water cooked samples. Acidic pH in lemon solution cooking may alter the rate of solubility of components during cooking.

Leaching of soluble constituents increased with cooking time which results in more porous structure of slices. Lower moisture content in flour of lemon cooked taro slices may be due to rapid moisture removal during drying because of porous structure of the slices. Irrespective of the cooking medium, moisture content of the flour increased with increase of microwave drying power levels. Higher microwave power level may cause rapid rate of moisture evaporation which can lead to surface burning at the end of drying process. Therefore, to avoid the chances for surface burning, the sample was withdrawn just prior to complete the drying process and therefore it results in higher moisture content as compared to sample dried at lower microwave power level. Proximate composition of the flour from steam cooked taro slices was not significantly ($p<0.05$) affected with cooking time.

The results of proximate composition of flour from water cooked taro slices are corroborated well with those reported by Kumar et al. (2015b). The proximate results of taro flour reported by Kaushal et al. (2012) is also in good agreement accept protein content. PCA loading plot (Figure 3) and Pearson correlation analysis (Table 2) showed that total carbohydrate was negatively correlated with moisture ($r= -0.97$, $p<0.05$), ash ($r= -0.96$, $p<0.05$), and protein content ($r= -0.95$, $p<0.05$) of taro flour samples.

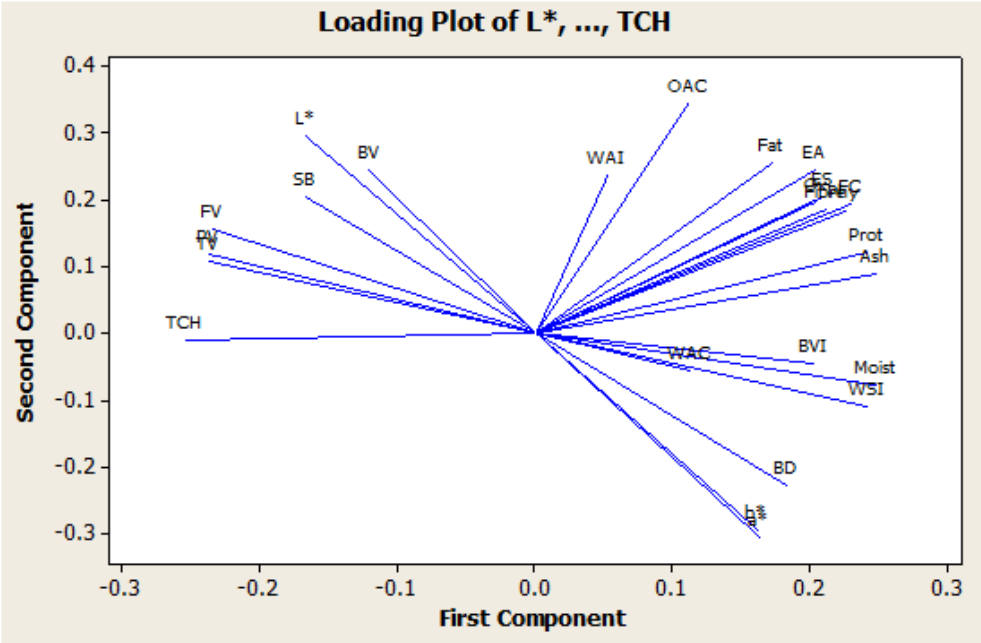

Figure 3. PCA loading plot of PC1 and PC2 describes the variation among different properties of flours. L*, a*, b*: Hunter color values; BD: Bulk density; WAI: Water absorption index; WSI: Water solubility index; BVI: Blue value index; WAC: Water absorption capacity; OAC: Oil absorption capacity; ES: Emulsion stability; EA: Emulsion activity; FC: Foaming capacity; PV: Peak viscosity; TV: Trough viscosity; BV: Breakdown viscosity; SB: Setback viscosity; FV: Final viscosity; Ox: Oxalate; Phy: Phytate; Mois: Moisture; Prot: Protein; TCH: Total carbohydrate.

Color characteristics

Hunter color values (L*, a*, b*) of different samples of taro flour are shown in Table 3. L* values for different flours varied from 64.8 to 78.7. Higher L* value gives a good visual perspective to the sample. Among the cooking medium, the highest L* value was observed in flour from taro slices cooked in lemon solution whereas the lowest in the flour from taro slices cooked in steam. No significant variation was observed in L* value of flours from slices cooked in water and lemon solution. L* value significantly decreased with increasing cooking time in all the cooking mediums. Maximum change in L* value was observed in flours from taro slices cooked in steam for 10 min. This may be due to starch gelatinization phenomenon, which occurred in shorter time in presence of superheated steam. Besides the cooking conditions, microwave drying at different power levels also affected the color of taro flour samples. It was observed that low microwave power level produced lesser changes in color. High microwave power level led to more browning and more chances of burning in the centre of the samples possibly due to concentrated heat. Hunter a* and b* values for different flours ranged between 1.5 to 5.9 and 18.2 to 28.5, respectively (Table 3). Taro flour had been reported to be white, less red and less yellow in color (Aboubakar et al., 2008). It has been hypothesized that the variation in b* value among samples may be attributed to the amount of carbohydrate and protein content and their role in the development of non-enzymatic browning (Njintang et al., 2003).

The difference in the colour characteristics of different flours may be attributed due to differences in leaching of colored pigments during cooking of taro slices in different medium. Therefore, among the different samples of taro flour, the sample from taro slices cooked in lemon solution and dried at 360W microwave power, showed the highest L* value, lowest a* and b* value. PCA loading plot (Figure 3) revealed a positive correlation of L* and negative correlation of a* and b* with carbohydrate content, respectively. Pearson correlation matrix also indicated the similar trend for carbohydrate with L* ($r= 0.61$, $p<0.05$), a* ($r= -0.59$, $p<0.05$) and b* ($r= -0.58$, $p<0.05$) (Table 2).

Physicochemical properties

Bulk density (BD)

BD of taro flour samples was 0.66 to 0.89 g/ml (Table 4). The BD of flour samples was highest in steam cooked taro than water cooked followed by lemon solution cooked slices. In steam cooking treatment of taro slices, the resulted gelatinized starch was probably broken down into lower molecular weight carbohydrate due to

Table 1. Proximate composition of flours from cooked as well as microwave drying taro slices.

Parameter	Microwave power (W)	FCW			FCL			FCS		
		5#	10	15	5	10	15	5	10	15
Moisture content (%)	720	12.6±0.4$^{a(a)}$	11.4±0.3$^{b(b)}$	11.5±0.3$^{b(b)}$	9.7±0.1$^{a(d)}$	9.2±0.5$^{ab(d)}$	8.6±0.2$^{b(e)}$	10.9±0.3$^{b(c)}$	10.6±0.3$^{b(c)}$	11.2±0.2$^{a(b)}$
	540	12.2±0.2$^{a(a)}$	10.8±0.2$^{b(b)}$	10.2±0.4$^{b(c)}$	9.1±0.2$^{a(d)}$	8.7±0.3$^{a(e)}$	8.0±0.2$^{b(f)}$	10.2±0.2$^{b(c)}$	10.5±0.4$^{ab(c)}$	11.0±0.3$^{a(b)}$
	360	11.2±0.2$^{a(a)}$	10.2±0.1$^{b(c)}$	10.0±0.2$^{b(c)}$	8.7±0.4$^{a(d)}$	8.2±0.2$^{ab(e)}$	8.0±0.2$^{b(e)}$	10.2±0.2$^{b(c)}$	10.1±0.2$^{b(c)}$	10.8±0.4$^{a(b)}$
Protein (%)	720	4.0±0.12$^{a(b)}$	3.8±0.07$^{b(c)}$	3.4±0.09$^{c(d)}$	3.8±0.11$^{a(bc)}$	3.1±0.12$^{b(e)}$	2.9±0.13$^{c(e)}$	4.6±0.20$^{a(a)}$	4.7±0.18$^{a(a)}$	4.6±0.13$^{a(a)}$
	540	4.2±0.09$^{a(c)}$	3.9±0.09$^{b(d)}$	3.4±0.13$^{c(e)}$	3.7±0.15$^{a(d)}$	3.4±0.10$^{b(e)}$	2.7±0.16$^{c(f)}$	4.5±0.18$^{b(b)}$	4.6±0.10$^{ab(b)}$	4.8±0.12$^{a(a)}$
	360	4.3±0.11$^{a(b)}$	3.9±0.16$^{b(c)}$	3.2±0.08$^{c(d)}$	3.8±0.12$^{a(c)}$	3.1±0.09$^{b(d)}$	2.9±0.10$^{c(f)}$	4.6±0.11$^{a(a)}$	4.4±0.09$^{a(a)}$	4.5±0.16$^{a(a)}$
Fat (%)	720	0.90±0.07$^{a(a)}$	0.90±0.03$^{a(a)}$	0.86±0.06$^{a(a)}$	0.84±0.07$^{a(a)}$	0.82±0.06$^{a(a)}$	0.80±0.09$^{a(a)}$	0.92±0.06$^{a(a)}$	0.88±0.05$^{a(a)}$	0.91±0.09$^{a(a)}$
	540	0.92±0.05$^{a(ab)}$	0.90±0.06$^{a(ab)}$	0.85±0.09$^{a(abc)}$	0.85±0.10$^{a(abc)}$	0.81±0.04$^{a(bc)}$	0.77±0.03$^{a(c)}$	0.90±0.04$^{a(ab)}$	0.94±0.08$^{a(a)}$	0.85±0.06$^{a(abc)}$
	360	0.98±0.09$^{a(a)}$	0.93±0.04$^{a(ab)}$	0.86±0.08$^{a(abc)}$	0.85±0.04$^{a(bc)}$	0.84±0.08$^{a(bc)}$	0.78±0.06$^{a(c)}$	0.95±0.07$^{a(ab)}$	0.98±0.06$^{a(a)}$	0.87±0.04$^{a(abc)}$
Ash (%)	720	4.92±0.11$^{a(b)}$	4.46±0.07$^{b(c)}$	4.25±0.10$^{c(d)}$	4.44±0.12$^{a(c)}$	4.20±0.10$^{b(de)}$	4.07±0.08$^{b(e)}$	5.22±0.06$^{a(a)}$	5.11±0.09$^{a(a)}$	5.10±0.10$^{a(a)}$
	540	4.76±0.10$^{a(b)}$	4.38±0.09$^{b(cd)}$	4.23±0.06$^{b(de)}$	4.52±0.09$^{a(c)}$	4.28±0.10$^{b(d)}$	4.10±0.09$^{b(e)}$	5.18±0.08$^{a(a)}$	5.20±0.07$^{a(a)}$	5.14±0.09$^{a(a)}$
	360	4.82±0.09$^{a(c)}$	4.41±0.11$^{b(d)}$	4.16±0.07$^{c(ef)}$	4.47±0.10$^{a(d)}$	4.21±0.07$^{b(e)}$	4.02±0.11$^{c(f)}$	5.26±0.11$^{a(a)}$	5.14±0.08$^{a(ab)}$	5.10±0.07$^{a(b)}$
Fibre (%)	720	2.84±0.12$^{a(a)}$	2.76±0.09$^{a(ab)}$	2.75±0.09$^{a(ab)}$	2.78±0.10$^{a(ab)}$	2.70±0.07$^{a(ab)}$	2.62±0.11$^{a(b)}$	2.88±0.10$^{a(a)}$	2.85±0.08$^{a(a)}$	2.82±0.05$^{a(a)}$
	540	2.85±0.08$^{a(a)}$	2.80±0.11$^{a(ab)}$	2.70±0.07$^{a(ab)}$	2.77±0.08$^{a(ab)}$	2.70±0.11$^{a(ab)}$	2.65±0.09$^{a(b)}$	2.85±0.10$^{a(a)}$	2.85±0.11$^{a(a)}$	2.80±0.06$^{a(a)}$
	360	2.80±0.07$^{a(a)}$	2.76±0.10$^{a(a)}$	2.72±0.11$^{a(a)}$	2.80±0.09$^{a(a)}$	2.72±0.06$^{a(a)}$	2.74±0.09$^{a(a)}$	2.86±0.11$^{a(a)}$	2.80±0.06$^{a(a)}$	2.82±0.11$^{a(a)}$
Total carbohydrate (%)	720	74.74±0.82$^{b(d)}$	76.68±0.56$^{a(c)}$	77.24±0.64$^{a(bc)}$	78.44±0.50$^{c(c)}$	79.98±0.85$^{b(ab)}$	81.01±0.61$^{a(a)}$	75.48±0.72$^{a(e)}$	75.86±0.70$^{a(e)}$	75.37±0.57$^{a(e)}$
	540	75.07±0.52$^{b(c)}$	77.22±0.55$^{a(b)}$	78.62±0.75$^{a(b)}$	79.06±0.62$^{b(b)}$	80.11±0.65$^{b(b)}$	81.78±0.57$^{a(a)}$	76.37±0.60$^{a(d)}$	75.91±0.76$^{a(d)}$	75.41±0.63$^{a(e)}$
	360	75.90±0.68$^{c(d)}$	77.80±0.51$^{b(bc)}$	79.06±0.54$^{a(a)}$	79.38±0.75$^{b(c)}$	80.93±0.50$^{a(ab)}$	81.56±0.56$^{a(a)}$	76.13±0.60$^{a(e)}$	76.58±0.49$^{a(e)}$	75.91±0.78$^{a(e)}$

Means ± SD with different superscript in a row differ significantly in each cooking medium and in bracket amongst the cooking medium ($p \leq 0.5$, n=3); FCW: Flours from taro slices cooked in water; FCL: flours from taro slices cooked in lemon solution; FCS: flours from taro slices cooked in steam; #Cooking time in min.

superheated moist heat treatment. These broken lower molecular weight compounds are present as such in the slices and were not leached out, which may result more compact structure and therefore can result into higher bulk density. In lemon solution cooking, starch hydrolysis was taken place due to the presence of acid. The hydrolyzed compounds were possibly leached out into the solution, which caused lower BD of the resulted flour. Whereas in case of cooking in water, starch gelatinization process was quite noticeable, structure formed was dense but due to higher degree of leaching of soluble carbohydrate during cooking, resulting flour was lesser dense as compared to steam treated sample.

The flour BD was increased with microwave power level and cooking time (Table 4). A maximum of 25% increased in BD of flour from taro slices cooked in water for 15 min whereas a minimum of 1.5% increased, when cooked in lemon solution for 5 min was observed during microwave drying of 360 to 720 W. BD directly correlated with cooking time as well. Increase in cooking time leads to increase in bulk density.

Table 2. Pearson correlation coefficient between various measured properties of flours fromcooked as well as microwave drying taro slices.

Correlation	L*	a*	b*	BD	WAI	WSI	BVI	WAC	OAC	ES	EA	FC	PV	TV	BV	SB	FV	Ox	Phy	Mois	Prot	Fat	Ash	Fibre
a*	-0.96																							
b*	-0.98	0.96																						
BD	-0.82	0.80	0.82																					
WAI	0.23	-0.27	-0.22	-0.01																				
WSI	-0.80	0.78	0.79	0.79	-0.03																			
BVI	-0.61	0.56	0.60	0.72	0.55	0.71																		
WAC	0.38	-0.39	0.38	0.49	0.49	0.30	0.66																	
OAC	0.26	-0.28	-0.27	-0.17	0.32	0.21	0.05	-0.03																
ES	-0.17	0.13	0.15	0.38	0.61	0.57	0.71	0.44	0.65															
EA	-0.06	0.04	0.03	0.21	0.46	0.56	0.53	0.22	0.77	0.89														
FC	-0.25	0.22	0.23	0.38	0.49	0.68	0.68	0.39	0.72	0.94	0.94													
PV	0.76	-0.74	-0.75	-0.82	-0.21	-0.89	-0.89	-0.56	-0.09	-0.64	-0.55	-0.70												
TV	0.75	-0.73	-0.74	-0.81	-0.25	-0.89	-0.90	-0.57	-0.10	-0.65	-0.56	-0.71	0.99											
BV	0.56	-0.61	-0.54	-0.53	0.55	-0.54	-0.15	-0.02	0.18	-0.05	-0.09	-0.11	0.52	0.48										
SB	0.64	-0.70	-0.59	-0.57	0.42	-0.69	-0.30	-0.16	0.03	-0.23	-0.31	-0.31	0.64	0.61	0.88									
FV	0.79	-0.79	-0.75	-0.80	-0.02	-0.90	-0.76	-0.47	-0.06	-0.56	-0.52	-0.63	0.96	0.95	0.69	0.82								
Ox	-0.16	0.14	0.14	0.20	0.11	0.63	0.32	0.05	0.82	0.75	0.88	0.87	-0.50	-0.49	-0.29	-0.42	-0.52							
Phy	-0.24	0.23	0.21	0.30	0.25	0.70	0.49	0.20	0.77	0.84	0.92	0.94	-0.63	-0.63	-0.25	-0.43	-0.62	0.97						
Mois	-0.74	0.73	0.71	0.72	-0.08	0.96	0.63	0.27	0.31	0.62	0.64	0.73	-0.85	-0.84	-0.61	-0.76	-0.89	0.74	0.78					
Prot	-0.41	0.36	0.37	0.45	0.22	0.81	0.62	0.26	0.64	0.83	0.87	0.93	-0.74	-0.74	-0.28	-0.46	-0.71	0.91	0.95	0.86				
Fat	-0.08	0.05	0.07	0.17	0.56	0.46	0.54	0.22	0.78	0.82	0.82	0.86	-0.45	-0.47	0.17	-0.02	-0.35	0.72	0.79	0.48	0.75			
Ash	-0.45	0.44	0.42	0.50	0.18	0.83	0.61	0.29	0.60	0.83	0.88	0.92	-0.76	-0.76	-0.38	-0.60	-0.78	0.90	0.94	0.90	0.95	0.71		
Fibre	-0.20	0.17	0.17	0.35	0.29	0.65	0.48	0.19	0.72	0.84	0.88	0.89	-0.56	-0.56	-0.22	-0.35	-0.54	0.88	0.91	0.73	0.89	0.72	0.86	
TCH	0.61	-0.59	-0.58	-0.63	-0.06	-0.93	-0.64	-0.28	-0.48	-0.75	-0.78	-0.85	0.83	0.82	0.49	0.66	0.84	-0.85	-0.89	-0.97	-0.95	-0.63	-0.96	-0.84

L*, a*, b*: Hunter color values; BD: Bulk density; WAI: water absorption index; WSI: water solubility index; BVI: blue value index; WAC: water absorption capacity; OAC: oil absorption capacity; ES: emulsion stability; EA: emulsion activity; FC: foaming capacity; PV: peak viscosity; TV: trough viscosity; BV: breakdown viscosity; SB: setback viscosity; FV: final viscosity; Ox: oxalate; Phy: phytate; Mois: Moisture; Prot: Protein; TCH: Total carbohydrate.

BD was maximum, when cooked for 15 min whereas lowest for 5 min. The observed effect of precooking time on the BD of taro flour corroborated with the results of Kumar et al. (2017b), who reported increase in BD of taro flour from 0.79 to 0.89 g/ml, 0.74 to 0.83 g/ml, and 0.85 to 0.90 g/ml, as the cooking time increased from 5 to 15 min in water, lemon solution and steam, respectively, whereas, Njintang and Mbofung (2006) reported 29% increase in BD. The high BD of taro flours suggests their suitability for use in food preparations. Higher BD is desirable for greater ease of dispersability of flours. In contrast, low BD would be an advantage in the formulation of complementary foods. It was important to note that BD was positively correlated with ash (r= 0.50, $p<0.05$) but negatively correlated with carbohydrate (r= -0.63, $p<0.05$) both by Pearson correlation (Table 2) and PCA analysis (Figure 3).

Water absorption index (WAI) and water solubility index (WSI)

WAI generally measures the amount of water

Table 3. Color characteristics of flours from cooked as well as microwave drying taro slices.

Color parameter	Microwave power (W)	FCW			FCL			FCS		
		5#	10	15	5	10	15	5	10	15
L*	720	71.0±1.3$^{ab(ab)}$	72.7±2.0$^{a(ab)}$	67.3±2.2$^{c(cd)}$	73.4±1.0$^{a(a)}$	70.7±1.9$^{a(ab)}$	69.4±2.5$^{a(bc)}$	70.8±1.7$^{a(ab)}$	65.3±1.8$^{b(d)}$	64.8±1.4$^{b(d)}$
	540	72.1±2.0 $^{a(a)}$	73.9±1.1$^{a(a)}$	71.9±1.4$^{a(a)}$	74.0±2.1$^{a(a)}$	74.0±2.1$^{a(a)}$	72.4±1.8$^{a(a)}$	72.6±0.8$^{a(a)}$	67.3±2.1$^{b(b)}$	66.5±1.1$^{b(b)}$
	360	76.5±2.1$^{a(abc)}$	77.1±2.6$^{a(ab)}$	73.2±1.2$^{a(cd)}$	78.7±2.3$^{a(a)}$	77.4±1.5$^{a(ab)}$	76.8±2.0$^{a(abc)}$	74.1±1.1$^{a(bcd)}$	70.5±2.4$^{ab(de)}$	69.1±2.6$^{b(e)}$
a*	720	4.3±0.8$^{ab(cd)}$	3.1±1.0$^{b(d)}$	5.6±1.3$^{a(abc)}$	3.4±0.5$^{b(d)}$	4.9±0.4$^{a(bc)}$	5.5±0.1$^{a(abc)}$	5.4±0.3$^{b(abc)}$	5.9±0.4$^{ab(ab)}$	6.4±0.5$^{a(a)}$
	540	3.4±0.6$^{a(b)}$	2.9±1.3$^{a(b)}$	3.9±0.9$^{a(b)}$	2.7±0.4$^{b(b)}$	2.7±0.6$^{b(b)}$	3.8±0.4$^{a(b)}$	3.8±0.3$^{b(b)}$	5.6±0.6$^{a(a)}$	5.9±0.3$^{a(a)}$
	360	2.2±0.2$^{ab(bcd)}$	1.6±0.3$^{b(d)}$	3.0±1.0$^{a(b)}$	1.5±0.4$^{b(d)}$	2.0±0.1$^{ab(cd)}$	2.2±0.0$^{a(bcd)}$	2.7±0.3$^{b(bc)}$	4.9±0.2$^{a(a)}$	5.3±0.3$^{a(a)}$
b*	720	24.5±1.2$^{ab(bcd)}$	22.2±1.2$^{b(cd)}$	26.0±1.3$^{a(ab)}$	21.9±0.9$^{b(d)}$	24.1±1.1$^{ab(bcd)}$	24.8±1.1$^{a(bc)}$	24.0±1.7$^{b(bcd)}$	28.1±1.9$^{a(a)}$	28.5±1.4$^{a(a)}$
	540	22.4±0.9$^{a(b)}$	21.2±1.5$^{a(bc)}$	23.4±0.9$^{a(b)}$	19.2±1.4$^{a(c)}$	21.2±1.6$^{ab(bc)}$	23.1±1.0$^{a(b)}$	22.0±1.1$^{b(b)}$	25.9±1.3$^{a(a)}$	26.5±2.0$^{a(a)}$
	360	18.7±1.9$^{b(c)}$	18.5±1.0$^{b(c)}$	22.0±0.9$^{a(ab)}$	18.2±1.7$^{a(c)}$	18.3±1.2$^{a(c)}$	18.3±1.0$^{a(c)}$	20.7±1.5$^{a(bc)}$	24.6±2.8$^{a(a)}$	24.7±1.4$^{a(a)}$

Means ± SD with different superscript in a row differ significantly in each cooking medium and in bracket amongst the cooking medium (p≤0.5, n=3); FCW: flours from taro slices cooked in water; FCL: flours from taro slices cooked in lemon solution; FCS: flours from taro slices cooked in steam #cooking time in min.

Table 4. Physicochemical properties of flours from cooked as well as microwave drying taro slices.

Parameter	Microwave power (W)	FCW			FCL			FCS		
		5#	10	15	5	10	15	5	10	15
Bulk density (g/ml)	720	0.82±0.05$^{a(b)}$	0.84±0.04$^{a(ab)}$	0.87±0.03$^{a(ab)}$	0.70±0.01$^{b(c)}$	0.74±0.02$^{a(c)}$	0.76±0.02$^{a(c)}$	0.84±0.04$^{a(ab)}$	0.84±0.03$^{a(ab)}$	0.89±0.02$^{a(a)}$
	540	0.74±0.04$^{a(cd)}$	0.78±0.03$^{a(bc)}$	0.81±0.03$^{a(ab)}$	0.69±0.02$^{b(d)}$	0.73±0.01$^{a(cd)}$	0.75±0.02$^{a(c)}$	0.82±0.04$^{a(ab)}$	0.84±0.03$^{a(a)}$	0.85±0.03$^{a(a)}$
	360	0.66±0.03$^{a(f)}$	0.68±0.02$^{a(ef)}$	0.70±0.02$^{a(def)}$	0.69±0.01$^{b(def)}$	0.72±0.01$^{a(cd)}$	0.73±0.02$^{a(cd)}$	0.76±0.02$^{b(bc)}$	0.80±0.02$^{ab(ab)}$	0.82±0.03$^{a(a)}$
WAI (g/100 g)	720	306±3.6$^{b(b)}$	309±2.6$^{b(b)}$	311±2.6$^{a(a)}$	240±3.6$^{c(d)}$	244±2.6$^{b(c)}$	244±2$^{a(b)}$	310±3.6$^{a(b)}$	257±2.6$^{b(e)}$	243±2.6$^{c(e)}$
	540	319±3$^{b(c)}$	328±2.6$^{b(c)}$	337±2$^{a(a)}$	244±1$^{c(d)}$	253±2.6$^{b(c)}$	260±3.4$^{a(b)}$	336±3.6$^{a(b)}$	283±2.6$^{b(d)}$	271±2.6$^{e(e)}$
	360	328±2$^{c(f)}$	349±1$^{b(e)}$	366±2$^{a(b)}$	253±1.7$^{c(d)}$	268±2.6$^{b(c)}$	281±2.6$^{a(a)}$	362±2$^{a(a)}$	308±1.2$^{b(c)}$	296±2$^{c(e)}$
WSI (g/100 g)	720	12.9±2.2$^{a(abc)}$	11.8±1.7$^{a(bc)}$	11.3±1.6$^{a(bc)}$	10.8±1.0$^{a(bc)}$	10.3±1.7$^{a(bc)}$	10.3±0.8$^{a(c)}$	15.7±2$^{a(ab)}$	16.2±1.1$^{a(ab)}$	18.6±1.5$^{a(a)}$
	540	11.7±1.2 $^{a(bcd)}$	10.1±1.6$^{a(d)}$	10.2±2.1$^{a(d)}$	9.6±0.9$^{a(bcd)}$	8.5±2.6$^{a(cd)}$	8.2±1.2$^{a(d)}$	13.5±0.4$^{b(abc)}$	13.8±0.4$^{b(ab)}$	15.5±0.5$^{a(a)}$
	360	9.7±1.1$^{a(c)}$	9.0±0.9$^{a(cd)}$	8.9±0.7$^{a(cd)}$	8.3±0.4$^{a(cde)}$	7.4±0.2$^{b(de)}$	7.1±0.3$^{b(e)}$	12.7±0.9$^{a(b)}$	13.0±1.6$^{a(b)}$	14.7±1.0$^{a(a)}$
BVI (eq DO/100 g)	720	8.3±0.3$^{c(c)}$	10.2±0.4$^{b(b)}$	13.2±0.4$^{a(a)}$	3.1±0.3$^{c(e)}$	4.3±0.3$^{b(de)}$	5.7±0.2$^{a(d)}$	12.7±1.9$^{a(a)}$	13.2±1.8$^{a(a)}$	13.7±0.3$^{a(a)}$
	540	8.2±0.3$^{c(c)}$	10.1±0.1$^{b(b)}$	13.1±0.3$^{a(a)}$	3.0±0.2$^{c(e)}$	4.2±0.3$^{b(e)}$	5.6±0.2$^{a(d)}$	12.6±1.7$^{a(a)}$	13.2±0.4$^{a(a)}$	13.6±1.2$^{a(a)}$
	360	7.9±0.3$^{c(bc)}$	9.4±0.5$^{b(b)}$	12.9±3.2$^{a(a)}$	3.1±0.1$^{c(d)}$	4.2±0.3$^{b(d)}$	5.5±0.2$^{a(cd)}$	12.5±2.7$^{a(a)}$	13.1±1.3$^{a(a)}$	13.5±1.7$^{a(a)}$

Means ± SD with different superscript in a row differ significantly in each cooking medium and in bracket amongst the cooking medium (p≤0.5, n=3); FCW: Flours from taro slices cooked in water; FCL: Flours from taro slices cooked in lemon solution; FCS: Flours from taro slices cooked in steam; #Cooking time in min.

absorbed by starch granules after swelling in excess of water and can be used as an index of gelatinization. WAI of taro flour samples are summarized in Table 4. WAI of different flour samples varied from 240 to366 g/100 g. In general, WAI of the flours from taro slices

cooked in water and lemon solution increased with increase of cooking time of slices. However, the rate of increase of WAI was lower in flours from lemon solution cooked taro slices probably due to presence of acids during cooking, which results two phenomenons. One was, it hinders the rate of starch gelatinization and other was acid hydrolysis of starch. Both of these phenomenon resulted lower WAI. On the other hand, flours from taro slices cooked in steam showed an inverse relation to WAI with cooking time. This may due to rupturing of gelatinized starch granules during steam cooking. The WAI of flours significantly decreased ($p<0.05$) with microwave power levels. The change in WAI with microwave power levels was more pronounced in steam cooked samples followed by water and lemon solution cooked samples. Rapid increase in temperature at higher microwave power level possibly led to rupture of starch granules and lost their integrity, which caused a decrease in WAI. PCA analysis (Figure 3) and Pearson correlation (Table 2) showed a positive correlation of WAI with EA ($r = 0.46$, $p<0.05$), ES ($r = 0.61$, $p<0.05$), WAC ($r = 0.49$, $p<0.05$), and BVI ($r = 0.55$, $p<0.05$) while a negative correlation with PV ($r = -0.21$, $p<0.05$) and TV ($r = -0.25$, $p<0.05$) of taro flour.

WSI is related to the presence of soluble molecules and often used as an indicator of degradation of molecular components. The WSI obtained in the different samples of taro flour ranged from 7.1 to 18.6 g/100 g (Table 4). WSI was observed maximum for flour from taro slices cooked in steam while minimum in lemon solution and intermediate in water cooked slices (Table 4). WSI of the flour samples decreased with increase of cooking time possibly due to leaching out of soluble constituents. But, the results were vice-versa in steam cooking. This may be due to formation of more soluble sugars during prolonged cooking and it remains in the slices due to negligible leaching. Njintang and Mbofung (2003) also reported significant increase in soluble sugars of taro slices during cooking. The much higher increase of soluble sugars content was reported for steam cooking of taro slices compared to water and acidic solution cooking due to faster heat exchange and of course higher rate of reaction (Aboubakar et al., 2009). Irrespective of the cooking conditions, WSI of the flours was increased with microwave power levels (Table 4). Higher value observed in steam cooking due to the presence of more pre-gelatinized starch which might be breakdown during microwave drying. Pearson correlation (Table 2) and PCA loading plot (Figure 3) revealed a positive correlation of WSI with oxalate content ($r = 0.63$, $p<0.05$), phytate content ($r = 0.70$, $p<0.05$), ash content ($r = 0.83$, $p<0.05$), moisture content ($r = 0.96$, $p<0.05$) and a negative with total carbohydrate ($r = -0.93$, $p<0.05$) and all pasting parameters.

Blue value index (BVI)

BVI is an indication of the degree of starch gelatinization. BVI of taro flour samples varied from 3.0 to 13.7 eq DO/100 g (Table 4). Irrespective of the cooking medium, BVI of taro flour samples increased significantly with cooking time, although at different rates. During the first 5 min of cooking, BVI increased rapidly in case of flour from slices cooked in steam. This relatively rapid increase in the BVI may due to the difference in heat exchange which caused gelatinization of starch granules. The BVI of flours from taro slices cooked in water and steam for 15 min were relatively similar but higher than the flours from lemon solution cooked taro slices. The lower BVI of flours from taro slices cooked in lemon solution suggests a lower degree of gelatinized starch and possibly be due to starch hydrolysis under these conditions. Njintang and Mbofung (2003) reported that gelatinization and hydrolysis of starch simultaneously occur during boiling of taro slices. The drying microwave power levels have no significant effect on the BVI of taro flour samples.

Functional properties

Water absorption capacity (WAC)

Water absorption characteristics represent the ability of a product to associate with water under conditions where water is limiting. WAC of prepared taro flour samples ranged from 150 to 230 g/100 g (Table 5). Cooking conditions and microwave power levels significantly ($p<0.05\%$) influenced the WAC of taro flour. It was observed that the flour prepared from steam cooked taro slices had higher WAC than flour samples from taro slices cooked in water and lemon solution. This effect was probably due to modification of starch and protein structure and presence of high amount of soluble sugars and protein in the flour samples. It was observed that with an increase of cooking time, the WAC of the flours increased. The increase in WAC has been associated with the increase in the amylose leaching and solubility, loss of starch crystalline structure and more hydrophilic constituents, such as polysaccharides. Inadequate gelatinization in lemon solution cooked samples may have more amount of crystalline structure, which may render decrease in WAC of flour. Microwave power levels had positive correlation with WAC of taro flour in all cooking treatments. However, it was more pronounced for higher cooking time.

High microwave power level may lead to higher proportion of amylose leaching and loss of crystalline structure due to the vibrational motion of the polar molecules during microwave heating. WAC of taro flour 2.447 g/g was reported by Kaushal et al. (2012). Aboubakar et al. (2008) suggested that the non-starch component of the flours such as mucilage contribute highly to the water absorption of taro flour. WAC of flour samples was negatively correlated with the pasting characteristics as revealed from PCA plot (Figure 3) and Pearson correlation matrix (Table 2).

Table 5. Functional properties of flours from cooked as well as microwave drying taro slices.

Parameter	Microwave power (W)	FCW			FCL			FCS		
		5[#]	10	15	5	10	15	5	10	15
WAC (g/100g)	720	188±2.6$^{c(c)}$	208±3.6$^{b(b)}$	223±3$^{a(a)}$	150±4.5$^{a(c)}$	176±7.2$^{a(bc)}$	198±5.5$^{a(b)}$	226±4$^{a(d)}$	230±6.5$^{a(d)}$	124±3.6$^{a(d)}$
	540	183±2$^{c(d)}$	196±1.7$^{b(bc)}$	211±4.3$^{a(a)}$	152±6.5$^{a(c)}$	168±5.2$^{a(bc)}$	186±3.4$^{a(ab)}$	211±4.5$^{a(de)}$	210±3.4$^{a(e)}$	215±5$^{a(e)}$
	360	178±3.5$^{c(cd)}$	187±5$^{b(b)}$	199±4$^{a(ab)}$	151±7.8$^{a(ab)}$	163±7$^{a(ab)}$	178±3.6$^{a(a)}$	201±2.6$^{a(c)}$	207±4$^{ab(cd)}$	211±5.5$^{b(d)}$
OAC (g/100g)	720	103±4.5$^{a(a)}$	99±5.2$^{a(a)}$	86±6.2$^{b(bc)}$	98±3.6$^{a(a)}$	95±5.5$^{ab(ab)}$	85±6.2$^{b(c)}$	102±3$^{a(a)}$	99±4.3$^{a(a)}$	93±6.5$^{a(abc)}$
	540	106±6$^{a(a)}$	100±5.5$^{ab(abc)}$	88±7$^{b(de)}$	98±4.3$^{a(abcd)}$	95±6.5$^{ab(bcde)}$	86±6.0$^{b(e)}$	104±4$^{a(ab)}$	100±2$^{ab(abc)}$	93±5.5$^{b(cde)}$
	360	110±5.1$^{a(a)}$	102±6.5$^{a(abc)}$	89±3.4$^{b(de)}$	100±4.5$^{a(bc)}$	97±3$^{ab(bcd)}$	88±5.5$^{b(e)}$	105±3.6$^{a(ab)}$	103±5.2$^{ab(abc)}$	94±5$^{a(a)}$
EA (%)	720	30±0.3$^{a(b)}$	28±1.1$^{b(b)}$	25±0.8$^{c(c)}$	26±1.2$^{a(c)}$	25±1.7$^{a(c)}$	22±1.5$^{b(d)}$	32±0.8$^{a(a)}$	30±0.7$^{a(b)}$	30±1.3$^{a(b)}$
	540	30±1.0$^{a(b)}$	27±1.1$^{b(c)}$	25±1.4$^{b(cd)}$	27±1.1$^{a(c)}$	25±0.7$^{b(cd)}$	23±0.6$^{c(d)}$	34±1$^{a(a)}$	31±1.3$^{a(b)}$	30±1$^{a(b)}$
	360	32±1.0$^{a(b)}$	30±0.4$^{b(bc)}$	27±1.0$^{c(de)}$	29±0.4$^{a(cd)}$	27±1.0$^{b(de)}$	26±0.3$^{b(e)}$	35±0.8$^{a(a)}$	32±1.7$^{ab(b)}$	31±2$^{b(bc)}$
ES (%)	720	28±0.2$^{a(abc)}$	27±1.1$^{ab(bc)}$	26±0.8$^{c(c)}$	23±1.8$^{a(d)}$	22±1.7$^{a(d)}$	21±1.2$^{a(d)}$	30±1.5$^{a(a)}$	29±1$^{ab(ab)}$	27±0.9$^{b(bc)}$
	540	29±0.5$^{a(ab)}$	28±0.6$^{ab(ab)}$	27±0.4$^{b(b)}$	25±0.8$^{a(c)}$	24±1$^{a(c)}$	22±0.7$^{b(d)}$	30±2$^{a(a)}$	28±0.5$^{a(ab)}$	28±2$^{a(ab)}$
	360	29±2.0$^{a(b)}$	26±0.8$^{b(c)}$	26±0.6$^{b(c)}$	26±0.7$^{a(c)}$	25±0.7$^{ab(c)}$	24±1$^{b(c)}$	32±2.1$^{a(a)}$	31±1.9$^{a(ab)}$	29±1$^{a(b)}$
Foaming capacity (%)	720	22±0.6$^{a(c)}$	19±0.4$^{b(d)}$	15±1$^{c(e)}$	15±0.2$^{a(e)}$	11±1.7$^{b(f)}$	8±0.5$^{c(g)}$	27±1$^{a(a)}$	25±0.5$^{b(b)}$	21±0.5$^{c(c)}$
	540	22±0.5$^{a(b)}$	20±1.0$^{b(c)}$	16±0.7$^{c(d)}$	16±0.2$^{a(d)}$	14±0.6$^{b(e)}$	9±0.7$^{c(f)}$	27±2$^{a(a)}$	26±1.5$^{ab(a)}$	23±0.6$^{b(b)}$
	360	24±0.5$^{a(b)}$	21±0.5$^{b(c)}$	17±0.6$^{c(d)}$	17±1$^{a(d)}$	14±0.5$^{b(e)}$	10±0.4$^{c(f)}$	28±1.6$^{a(a)}$	27±0.7$^{a(a)}$	24±1.7$^{b(b)}$

Means ± SD with different superscript in a row differ significantly in each cooking medium and in bracket amongst the cooking medium (p≤0.5, n=3); FCW: Flours from taro slices cooked in water; FCL: flours from taro slices cooked in lemon solution; FCS: flours from taro slices cooked in steam; [#]Cooking time in min.

Oil absorption capacity (OAC)

OAC is the ability of the flour protein to physically bind fat by capillary attraction. It has great importance, since fats act as flavour retainer and also increases the mouth feel of the foods (Kaushal et al., 2012). The OAC of different taro flour samples is shown in Table 5. OAC values of flour samples range from 85 to 110 g/100 g. Flour prepared from steam and water cooked taro slices showed the highest OAC than lemon solution cooked slices. This variation in OAC may be due to the presence of acid in lemon solution cooking which may dissolve the soluble proteins that get leached out during cooking. Aboubakar et al. (2009) also reported in the study that the soluble proteins are the major constituents which affect the OAC of flour and the highest decrease was found in soluble proteins in the taro slices cooked in lemon solution. It was also observed from PCA loading plot (Figure 3) and Pearson correlation matrix (Table 2) that OAC had positive correlation ($r= 0.640$, $p<0.05$) with protein content of the flours.

Significant ($p<0.05$) variation was noted in the OAC of the flours from the cooked taro slices at 5, 10 and 15 min. Irrespective of the microwave powers and cooking medium, OAC of the flours decreased significantly during 5 to 15 min of cooking. The observation showed that OAC decreased with increase in cooking time. These results can be explained by increased leaching of the proteins with cooking time. The flour samples showed slight variation in OAC with microwave power levels. This variation may be due to surface hydrophobicity and denaturation at high microwave power. Variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of the oil among the flours, possibly explain the differences in the oil binding capacity of the flours (Adebowale and Lawal, 2004). OAC showed a positive correlation with EA, ES, and FC in PCA loading plot (Figure 3).

Emulsifying activity (EA) and emulsion stability (ES)

EA is defined as the ability of the flour to emulsify oil. Proteins being the surface active agents can

form and stabilize the emulsion by creating electrostatic repulsion on oil droplet surface (Makri et al., 2005). The function of proteins as emulsifiers in foods is recognized as a result of the binding proteins with water and oil simultaneously. In food system, the balance of hydrophilic and hydrophobic groups of protein is essential for emulsifying properties.

EA and ES of the taro flour samples ranged from 22 to 35% and 21 to 32%, respectively (Table 5). Among the different cooking medium, lemon solution cooked slices flour showed the lowest EA and ES. This may be due to highest leaching of soluble protein during cooking of taro slices whereas steam pressure cooked slices flour showed the highest EA and ES, which may be due to negligible loss of soluble protein. Cooking time showed the negative correlation with the EA and ES of the taro flour samples. Emulsion properties of the flour were not significantly affected by microwave power but slightly decreased with microwave power levels. Structural modification of protein and imbalance of hydrophilic and hydrophobic groups might be happen at higher microwave power which cause decrease in emulsion properties. EA and ES are positively correlated ($r= 0.896$, $p<0.05$) with each other but negatively correlated with pasting parameters and carbohydrate as shown in Pearson correlation matrix (Table 2)

Foaming capacity (FC)

Foams are used to improve texture, consistency and appearance of food products. Foam ability is related to the rate of decrease of the surface tension of air/water interface caused by absorption of protein molecules. FC of different flour samples ranged from 8 to 28% (Table 5). This variation in FC might be due to the different cooking conditions and drying method. Tagodoe and Nip (1994) reported FC, 29 to 31% for three different varieties of taro flour and also suggested that the foaming capacity of taro flour could be due to its mucilage (a soluble glycoprotein) content and that it is negatively affected by heating. The foaming of taro flours is due to its proteins content which forms a continuous cohesive film around the air bubbles in the foam (Kumar et al., 2017b). Graham and Phillips (1976) observed that flexible protein molecules such as β-caseincan rapidly reduce surface tension and gave good foam ability, whereas a highly ordered globular protein molecule such as lysozyme is relatively difficult to denature surface and gave low foam ability.

The flours from taro slices cooked in lemon solution showed lowest FC whereas steam cooked slices flour showed the highest FC. Higher values of FC in steam cooking might be due to negligible leaching of soluble proteins. The decrease in soluble proteins was highest, when slices cooked in lemon solution, which may due to leaching out of the soluble proteins at acidic pH. The decrease in soluble proteins has been reported to be highest for lemon and tamarind cooking corms samples and lowest in steam cooked slices (Aboubakar et al., 2009). Microwave power levels negatively affected the FC of the flour, which may causes due to opening up of the hydrophobic groups which leads to loss of protein solubility at higher microwave power levels. Foaming capacity was positively correlated to the protein ($r= 0.934$, $p<0.05$), fat content ($r= 0.863$, $p<0.05$) oxalate ($r= 0.873$, $p<0.05$) and phytate content ($r= 0.9451$, $p<0.05$) and negatively correlated with carbohydrate ($r= -0.853$, $p<0.05$) as revealed by Pearson correlation (Table 2) and PCA analysis (Figure 3).

Pasting properties

The pasting characteristics play an important role in the selection of a variety for use in the industry as a thickener, binder or for any other use. The pasting behavior of taro flours was studied by observing changes in the viscosity of a starch system based on the rheological principles. Pasting properties of different taro flour samples has been represented in Table 6. Significant difference was observed in pasting characteristics of different flours during heating and cooling cycles in excess of water. When a sufficient number of granules become swollen, a rapid increase in viscosity occurs, known as peak viscosity (PV). PV of different samples of taro flour ranged between 302 and 1725 cP (Table 6). PV was decreased with increase of cooking time and microwave power levels. The decrease in PV reflects greater degradation and gelatinization of starch. The drop in PV was more severe for samples treated with steam cooking than other cooking methods. The decrease in peak viscosity can be attributed to the changes in granular structures during the gelatinization. Katopo et al. (2002) reported that under the pressure treatment, the native crystalline structure was partially altered and its pasting properties were changed. Highest peak viscosity was recorded in lemon solution cooked samples. The acid may hinder the gelatinization which may result more un-gelatinized starch in the flour. The maximum effect of cooking time was observed in water cooked samples and minimum in steam pressure cooked samples. The lowering of peak viscosity with increase in microwave power level could be ascribed due to thermal degradation of amylopectin and amylose granules during drying.

Trough viscosity (TV) is influenced by the rate of amylose exudation, granule swelling, amylase-lipid complex formation and competition between exudated amylose and remaining granules for free water. Trough or holding viscosity of different flours ranged between 290 and 1673 cP (Table 6). Breakdown viscosity (BV) of flours ranged between 12 and 109 cP. The mean BV of the steam cooked samples (12-43 cP) was considerably lower than those of the other samples (22-109 cP). This

Table 6. Pasting properties of flours from cooked as well as microwave drying taro slices.

Parameter	Microwave power (W)	FCW			FCL			FCS		
		5#	10	15	5	10	15	5	10	15
Peak viscosity (cP)	720	1183±6.0$^{b(c)}$	928±7.2$^{a(b)}$	830±5.5$^{c(e)}$	1306±7.2$^{a(a)}$	1260±3.6$^{c(f)}$	1304±9.1$^{b(d)}$	346±5.2$^{a(g)}$	329±5.5$^{b(h)}$	302±4.5$^{c(i)}$
	540	1276±8.5$^{a(d)}$	1018±4$^{b(b)}$	901±8.1$^{c(c)}$	1485±5.5$^{c(f)}$	1413±7.0$^{b(e)}$	1429±7.8$^{a(a)}$	492±4.3$^{c(i)}$	441±3.6$^{a(g)}$	374±3.4$^{b(h)}$
	360	1536±9.8$^{b(d)}$	1291±4.5$^{a(c)}$	1049±9.1$^{c(f)}$	1725±5.0$^{b(b)}$	1631±3.4$^{c(g)}$	1605±10.8$^{a(a)}$	563±5.2$^{a(e)}$	501±3.0$^{c(i)}$	412±5.5$^{b(h)}$
Trough viscosity (cP)	720	1123±9.5$^{b(c)}$	874±10.1$^{a(b)}$	780±6.5$^{c(d)}$	1284±7.2$^{a(a)}$	1236±4.0$^{c(f)}$	1254±6.0$^{b(e)}$	318±6.0$^{a(g)}$	312±4.0$^{b(h)}$	290±3.0$^{c(i)}$
	540	1207±8.1$^{c(d)}$	955±5.2$^{a(b)}$	837±4.3$^{b(c)}$	1447±4$^{a(f)}$	1366±88$^{c(e)}$	1368±5.2$^{b(a)}$	454±3.6$^{a(i)}$	415±5.2$^{b(g)}$	356±3.4$^{c(h)}$
	360	1427±4.5$^{b(d)}$	1187±5.1$^{a(c)}$	974±6.2$^{c(e)}$	1673±7.2$^{b(b)}$	1599±4$^{a(f)}$	1566±7.5$^{c(a)}$	520±4.0$^{c(i)}$	483±3$^{a(h)}$	393±1.7$^{b(g)}$
Breakdown viscosity (cP)	720	60±2.6$^{b(b)}$	54±3.6$^{a(a)}$	50±2.0$^{a(a)}$	22±0.5$^{b(e)}$	24±0.2$^{b(e)}$	50±2.0$^{a(c)}$	28±0.6$^{a(d)}$	17±0.8$^{b(f)}$	12±1.7$^{c(g)}$
	540	69±2.0$^{b(c)}$	63±2.6$^{c(d)}$	64±1.0$^{a(b)}$	38±2.9$^{c(f)}$	47±3.1$^{b(e)}$	61±4.3$^{a(a)}$	38±1.3$^{a(f)}$	26±0.8$^{b(g)}$	18±1.0$^{c(h)}$
	360	109±3.6$^{b(b)}$	104±5.5$^{a(a)}$	75±5.1$^{c(d)}$	52±4.0$^{a(e)}$	32±2.1$^{b(g)}$	39±2.9$^{c(f)}$	43±4.3$^{a(c)}$	18±2.0$^{b(h)}$	19±2.0$^{b(h)}$
Setback viscosity (cP)	720	677±6.0$^{b(c)}$	765±6.2$^{a(a)}$	661±5.1$^{b(b)}$	566±5.1$^{b(d)}$	438±6.0$^{c(e)}$	423±4$^{a(b)}$	290±3.0$^{a(f)}$	241±4.3$^{b(g)}$	217±4.0$^{c(h)}$
	540	711±5.2$^{c(c)}$	806±6.0$^{b(b)}$	864±5.5$^{a(a)}$	480±5.2$^{c(f)}$	674±4.3$^{b(e)}$	697±5.1$^{a(d)}$	317±5.5$^{a(g)}$	271±4.5$^{b(h)}$	234±3.6$^{c(i)}$
	360	882±4.3$^{b(b)}$	1099±8.7$^{a(a)}$	899±6.0$^{c(d)}$	813±3$^{a(c)}$	495±3.6$^{c(f)}$	520±3$^{b(e)}$	406±7.5$^{a(d)}$	339±5.2$^{b(g)}$	238±3.0$^{b(g)}$
Final viscosity (cP)	720	1800±6.9$^{b(c)}$	1639±6.2$^{a(a)}$	1441±6.5$^{c(e)}$	1850±8.7$^{a(b)}$	1674±7.9$^{c(f)}$	1677±6.5$^{b(d)}$	608±9.0$^{a(g)}$	553±5.5$^{b(h)}$	507±5.0$^{c(i)}$
	540	1918±7.9$^{c(d)}$	1761±5.5$^{a(b)}$	1701±7$^{b(c)}$	1927±8.1$^{c(f)}$	2040±9.1$^{b(e)}$	2065±6.2$^{a(a)}$	771±7.0$^{b(h)}$	686±5.2$^{a(g)}$	590±4.0$^{c(i)}$
	360	2309±8.8$^{b(d)}$	2286±8.0$^{a(a)}$	1873±6.5$^{c(f)}$	2486±7.9$^{a(b)}$	2094±6$^{c(g)}$	2086±8.7$^{b(c)}$	926±10.4$^{a(e)}$	822±4.3$^{c(i)}$	631±5.0$^{b(h)}$

Means ± SD with different superscript in a row differ significantly in each cooking medium and in bracket amongst the cooking medium (p≤0.5, n=3); FCW: Flours from taro slices cooked in water; FCL: flours from taro slices cooked in lemon solution; FCS: flours from taro slices cooked in steam; #Cooking time in min.

is because of the small PV value (302-563 cP) of the former compared with the others (830-1725 cP). At BV, the swollen granules are disrupted further and amylose molecules may generally leach out into the solution and align in the direction of the shear.

Setback viscosity (SB) and final viscosity (FV) varied between 217 to 1099 cP and 507 to 2486 cP, respectively (Table 6). The SB also followed the trend of BV. The highest SB (1099 cP) was recorded for flour from taro slices cooked in water, and the lowest (217 cP) for flour from taro slices cooked in steam. Kaur et al. (2013) reported setback viscosity of taro flour was 560 cP. Setback viscosity is a measure of the syneresis of starch upon cooling of cooked starch pastes. Low setback value of taro flour indicates its lower tendency to retrograde. The smaller tendencies to retrograde are advantageous in food products such as soups and sauces, which undergo loss of viscosity and precipitation. Final viscosity had significant difference (p<0.05) with in cooking medium and different cooking medium. Steam cooked taro flour samples had lowest final viscosity (507 cP) compared to water cooked (1441 cP) and lemon solution cooked (1674 cP) flour samples. Final viscosity indicates the ability of the material to form a viscous paste. Final viscosity is largely determined by the retro - gradation of soluble amylose upon cooling. However, the increase in final viscosity (FV) might be due to the aggregation of the amylose molecules (Patil et al., 2020). All pasting properties parameters are highly positively correlated with each other and carbohydrate content of the flour as observed from the PCA loading plot (Figure 3).

Pasting properties of starch have been reported to be affected by amylose and lipid content and by branch chain length distribution of amylopectin. Although starch is quantitatively major component to control the pasting properties, temperature induced changes in non-starchy polysaccharides and proteins also contribute to the gelling and pasting properties by way of swelling,

Table 7. Anti-nutritional properties of flours from cooked as well as microwave drying taro slices.

Parameter	Microwave power (W)	FCW			FCL			FCS		
		5#	10	15	5#	10	15	5#	10	15
Oxalate content (mg/100g)	720	102.1±4.3$^{a(b)}$	80.2±2.3$^{b(d)}$	56.5±2.3$^{c(f)}$	95.5±2.9$^{a(c)}$	62.9±1.3$^{b(e)}$	19.4±2.1$^{c(g)}$	109.2±0.9$^{a(a)}$	100.7±1.4$^{a(a)}$	91.0±2.0$^{b(b)}$
	540	105.2±2.9$^{a(c)}$	80.0±2.3$^{b(e)}$	50.8±1.6$^{c(g)}$	96.2±2.6$^{a(d)}$	65.5±1.9$^{b(f)}$	20.8±2.2$^{c(h)}$	110.2±2.0$^{a(a)}$	100.5±1.3$^{b(b)}$	93.5±2.4$^{c(c)}$
	360	105.9±3.4$^{a(c)}$	82.4±2.1$^{b(e)}$	52.4±2.8$^{c(g)}$	98.8±1.8$^{a(d)}$	66.4±1.7$^{b(f)}$	22.7±2.0$^{c(h)}$	110.0±1.0$^{a(a)}$	102.2±0.9$^{b(b)}$	94.3±2.4$^{b(b)}$
Phytate content (mg/100g)	720	70.2±2.4$^{a(d)}$	51.7±2.4$^{b(e)}$	37.1±3.1$^{c(f)}$	68.0±1.6$^{a(de)}$	42.3±2.7$^{b(f)}$	17.9±1.9$^{c(g)}$	74.7±1.0$^{a(a)}$	63.7±2.0$^{b(b)}$	57.2±1.0$^{c(c)}$
	540	71.7±2.9$^{a(c)}$	51.8±2.5$^{b(d)}$	36.0±1.9$^{c(e)}$	69.6±2.1$^{a(d)}$	44.5±2.2$^{b(e)}$	15.1±1.9$^{c(f)}$	74.6±1.7$^{a(a)}$	65.8±1.9$^{b(b)}$	58.5±1.5$^{b(bc)}$
	360	72.4±2.8$^{a(c)}$	53.3±0.6$^{b(d)}$	39.5±2.0$^{c(e)}$	70.4±1.5$^{a(d)}$	45.3±1.8$^{b(e)}$	18.5±1.5$^{c(f)}$	75.6±0.8$^{a(a)}$	66.8±2.0$^{ab(ab)}$	60.9±1.9$^{b(bc)}$

Means ± SD with different superscript in a row differ significantly in each cooking medium and in bracket amongst; the cooking medium ($p \leq 0.5$, n=3); FCW: Flours from taro slices cooked in water; FCL: flours from taro slices cooked in lemon solution; FCS: flours from taro slices cooked in steam; #Cooking time in min.

denaturation and unfolding (Kaur and Sandhu, 2010). Overall, these pasting properties can be attributed to the differences of physical structure of taro starch altered with various cooking medium and microwave power levels.

Anti-nutritional properties

The results of anti-nutritional properties of taro flour samples are shown in Table 7. Flour samples from taro slices cooked in lemon solution and water for an interval of 5-15 min showed the maximum reduction of oxalate content from 95.5 to 19.4 mg/100 g and 105.2 to 50.8 mg/100 g, respectively. This suggests that cooking in lemon solutions tends to hydrolyze and dissolve the crystals oxalates along with leaching into the cooking water. Minimum reduction in oxalate content from 109.2 to 91.0 mg/100 g was observed in flours from taro slices cooked in steam for 5 to 15 min. According to Savage (2000), relatively moderate or small losses of insoluble oxalate (crystals) occur during steam cooking of most foods. Aboubkar et al. (2009) reported that 10 and 25 min cooking in lemon solution and water respectively was required for complete elimination of itching sensation. The oxalate content of flour samples fairly decreased with increase of drying microwave power levels. This could be due to partially breakdown of oxalate crystal at such high microwave power levels. Similar trends of cooking time in different cooking medium were observed for phytate content of the flour. A positive correlation of oxalate and phytate content with ash ($r = 0.899$, $p<0.05$ and $r = 0.942$, $p<0.05$ respectively) and negative correlation with carbohydrate ($r = -0.849$, $p<0.05$ and $r = -0.890$, $p<0.05$ respectively) was observed in Pearson correlation matrix (Table 2).

Conclusions

The study's results revealed that taro flour has great potential for use in the food industry, especially in formulating new processed products. Taro flour exhibited variations in physicochemical, functional, pasting, and anti-nutritional properties based on cooking treatment and microwave drying power levels. Taro flours from slices cooked in a lemon solution showed the highest L* value. Flours from slices cooked in water exhibited the highest WAI, OAC, and intermediate emulsion properties, foaming capacity (FC), and WSI. This makes it potentially useful in flavor retention, improving palatability, and extending shelf life in meat products. Taro flour exhibited lower oxalate and phytate content with all cooking treatments, but the lemon cooking treatment was more effective in further reducing oxalate and phytate content. Flour from taro slices cooked in water and steam showed the highest bulk density, making it more suitable for child feeding due to its lower paste thickness. Flour from water-cooked taro slices had the highest peak viscosity compared to other precooking treatments. The high WAC and PV of taro flour indicate its usefulness as a potential thickener or gelling agent in various food products. The flours from taro slices cooked in water and steam showed higher values of physicochemical and functional properties. Higher L* value of color and pasting properties was observed in flour prepared from lemon-cooked slices. Additionally, it had lower

oxalate and phytate content, making it a favorable choice.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Aboubakar NY, Scher J, Mbofung CM (2009). Texture, microstructure and physicochemical characteristics of taro (*Colocasia esculenta*) as influenced by cooking conditions. Journal of Food Engineering 91:373-379.

Aboubakar YN, Scher J, Mbofung CM (2008). Physicochemical, thermal properties and microstructure of six varieties of taro *(Colocasia esculenta L. Schott*) flours and starches. Journal of Food Engineering 86:294-305.

Adebowale KO, Lawal OS (2004). Comparative study of the functional properties of bambarra groundnut (*Voandzeia subterranean*), jackbean (*Canavalia ensiformis*) and mucuna bean (*Mucuna pruriens*) flours. Food Research International 37:355-365.

Adegbaju OD, Otunola GA, Afolayan AJ (2019). Proximate, mineral, vitamin and anti-nutrient content of Celosia argentea at three stages of maturity. South African Journal of Botany 124:372-379.

Ammar MS, Hegazy AE, Bedeir SH (2009). Using of taro flour as partial substitute of wheat flour in bread making. World Journal of Dairy and Food Sciences. 4:94-99.

Amon AS, Soro RY, Assemand EF, Dué EA, Kouamé LP (2014). Effect of boiling time on chemical composition and physico-functional properties of flours from taro (*Colocasia esculenta* cv fouê) corm grown in Côte d'Ivoire. Journal of Food Science and Technology. 51:855-864.

AOAC (2005). Official methods of analysis, Association of Official Analytical Chemists, 18th Edition, Washington, D. C.

Arıcı M, Özülkü G, Kahraman B, Yıldırım RM, Toker ÖS (2020). Taro flour usage in wheat flour bread and gluten-free bread: Evaluation of rheological, technological and some nutritional properties. Journal of Food Process Engineering 43(9):e13454.

Bhattacharyya P, Ghost U, Gangopadhyay H, Raychaudhuri U (2006). Physicochemical characteristics of extruded snacks prepared from rice (*Oryza sativa* L.), Corn (*Zea mays* L.) and taro (*Colocasia esculenta* L.) by twin-screw extrusion. Journal of Scientific and Industrial Research 65:165-168.

Bradbury JH, Holloway WD (1988). Chemistry of Tropical Root Crops. Significance for Nutrition and Agriculture in the Pacific, Canberra. Australian Centre for International Agricultural Research (ACIAR) Monograph pp. 116-117.

Chandra S, Singh S, Kumari D (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. Journal of Food Science and Technology 52:3681-3688.

Emmanuel-Ikpeme CA, Eneji CA, Essiet U (2007). Storage stability and sensory evaluation of taro chips fried in palm oil, palm olein oil, groundnut oil, soybean oil and their blends. Pakistan Journal of Nutrition 6:570-575.

Giri NA, Sajeev MS (2020). Physico-mechanical and nutritional evaluation of taro (*Colocasia esculenta*) flour-based gluten-free cookies. Agricultural Research 9:125-131.

Graham DE, Phillips MC (1976). The conformation of proteins at air water interface and their role in stabilizing foam. In: Foams, RJ Akers, (ed.), London, UK. Academic Press pp. 237-277

Himeda M, Njintang Yanou N, Fombang E, Facho B, Kitissou P, Mbofung CM, Scher J (2014). Chemical composition, functional and sensory characteristics of wheat-taro composite flours and biscuits. Journal of Food Science and Technology 51:1893-1901.

Hung PV, Duy TL (2012). Effects of drying methods on bioactive compounds of vegetables and correlation between bioactive compounds and their antioxidants. International Food Research Journal 19:327-332.

Katopo H, Song Y, Jane J (2002). Effect and mechanism of ultrahigh hydrostatic pressure on the structure and properties of starches. Carbohydrate Polymers 47:233-244.

Kaur M, Kaushal P, Sandhu KS (2013). Studies on physicochemical and pasting properties of taro (*Colocasia esculenta* L.) flour in comparison with a cereal, tuber and legume flour. Journal of Food Science and Technology 50:94-100.

Kaur M, Sandhu KS (2010). Functional, thermal and pasting characteristics of flours from different lentil (*Lens culinaris*) cultivars. Journal of Food Science and Technology 47:273-278.

Kaushal P, Kumar V, Sharma HK (2012). Comparative study of physicochemical, functional, antinutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*) flour, pigeonpea (*Cajanus cajan*) flour and their blends. LWT- Food Science and Technology 48:59-68.

Kaushal P, Kumar V, Sharma HK (2013). Utilization of taro (*Colocasia esculenta*): A review. Journal of Food Science and Technology 52(1):27-40.

Kaushal P, Sharma HK (2014). Effect of incorporating taro (*Colocasia esculenta*), rice (*Oryza sativa*) and pigeonpea (*Cajanus cajan*) flour blends on noodle properties. International Journal of Food Properties 17(4):765-781.

Kumar V, Sharma HK, Kaushal P, Singh K (2015b). Optimization of taro–wheat composite flour cake using Taguchi technique. Food Measure 9(1):35-51.

Kumar V, Sharma HK, Singh K (2017b). Effect of precooking on drying kinetics of taro (*Colocasia esculenta*) slices and quality of its flours. Food Bioscience 20:178-186.

Kumar V, Sharma HK, Singh K, Kaushal P, Singh RP (2017a). Effect of pre-frying drying on mass transfer kinetics of taro slices during deep fat frying. International Food Research Journal 24(3):1110-1116.

Kumar V, Sharma HK, Singh K, Singh RP (2015a). Optimization of process parameters for the production of taro chips using RSM with fuzzy modeling. Food Measure 9(3):400-413.

Lin MJY, Humbert ES, Sosulski FW (1974). Certain functional properties of sunflower meal products. Journal of Food Science 39:368-370.

Makri E, Papalamprou E, Doxastakis G (2005). Study of functional properties of seed storage proteins from indigenous European legume crops (lupin, pea, and broad bean) in admixture with polysaccharides. Food Hydrocolloids 19:583-594.

Naczk M, Diosady LL, Rubin LJ (1985). Functional properties of canola meals produced by two-phase solvent extraction systems. Journal of Food Science 50:1685-1692.

Njintang YN, Mbofung CMF (2003). Development of taro (*Colocasia esculenta* (L.) Schott) flour as an ingredient for food processing: Effect of gelatinisation and drying temperature on the dehydration kinetics and colour of flour. Journal of Food Engineering 58:259-265.

Njintang YN, Mbofung CMF (2006). Effect of precooking time and drying temperature on the physico-chemical characteristics and in-vitro carbohydrate digestibility of taro flour. LWT- Food Science and Technology 39:684-691.

Njintang YN, Nguimbou RM, Scher J, Mbofung CMF (2010). Effect of storage on the physicochemical, functional and rheological properties of taro (*Colocasia esculenta*) flour and paste. Innovative Romanian Food Biotechnology 7:37-48.

Patil S, Sonawane SK, Mali M, Mhaske ST, Arya SS (2020). Pasting, viscoelastic and rheological characterization of gluten free (cereals, legume and underutilized) flours with reference to wheat flour. Journal of Food Science and Technology 57: 2960-2966.

Rodríguez MJ, Ruiz-López II, Herman-Lara E, Martínez-Sánchez CE, Delgado Licon E, Vivar-Veraa MA (2011) Development of extruded snacks using taro (*Colocasia esculenta*) and nixtamalized maize (*Zea mays*) flour blends. LWT- Food Science and Technology 44:673–680.

Savage M (2000). Effect of cooking on the soluble and insoluble oxalate content of some New Zealand foods. Journal of Food Composition and Analysis 13:201-206.

Soudy ID, Oliveira LA, Nzouzi NL, Godefroy M, Arada IA, Atteib OD, Alhadj D, Idriss AO (2014). Comparison of the effectiveness of different traditional soaking processes on the in vitro digestibility of taro (*Colocasia esculenta* L. SCHOTT) Flour. Food and Nutrition

Sciences 5:258-263.
Tagodoe A, Nip WK (1994). Functional properties of raw and precooked taro (*Colocasia esculenta*) flours. International Journal of Food Science and Technology 29:457-462.
Tekle A (2009). The effect of blend proportion and baking condition on the quality of cookies made from taro and wheat flour blend. Thesis Addis Ababa University, Ethiopia.
Wang CR, Chang KC, Grafton K (1988). Canning quality of pinto and navy beans. Journal of Food Science 53:772-776.
Wheat SO (2019). Using of taro (*Colocasia esculenta*) flour as a partial substitute of wheat flour in biscuit making. Environmental Science 14(1):235-246.
Workneh TS, Raghavan V, Gariepy Y (2011). Microwave assisted hot air ventilation drying of tomato slices. In: International conference on food engineering and biotechnology. IACSIT Press, Singapore. pp. 150-161.

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