



Application of Arvi (*Colocasia esculenta*) derived starch in improving the rheological properties of yogurt

Umair Ali^{1*}, Hammad Hafeez¹, Hafiz Talha Hafeez¹, Amara Shafqat² and Areej Nasir¹

¹Department of Food Science and Technology, Faculty of Agriculture and Environment, The Islamia University of Bahawalpur, Bahawalpur-63100, Punjab, Pakistan

²National Institute of Food Science and Technology, University of Agriculture Faisalabad, Faisalabad-38040, Punjab, Pakistan

Article Info

Keywords:

Colocasia esculenta starch;
Rheological properties; Textural enhancement; Functional food ingredients

Date:

Received: 17 December 2022

Accepted: 12 September 2023

Published: 30 December 2023

Volume: 01 (01), 2023



Copyright: © 2023 by the authors. This article is distributed under the Creative Commons Attribution (CC BY) license, allowing for open access and sharing under specified terms and conditions.
(<https://creativecommons.org/licenses/by/4.0/>).

Abstract

Stabilizers are used in the food industry, particularly during yogurt manufacturing to improve the texture, mouth feel, and appearance. In the present study, starch was extracted from the Arvi plant. The extraction of starch was carried out with and without the use of chemicals. The yogurt was prepared with the help of bacterial starter culture i.e., *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. Different levels of Arvi starch (0.1, 0.2, 0.3, 0.4, and 0.5%) were used in the preparation of yogurt along with culture. The control was prepared by using 0.5% gelatin. Yogurt samples were observed for their texture, pH, syneresis, total solids, acidity, water-holding capacity, and organoleptic characteristics. These characteristics were also analyzed after the 7 and 15 days of storage. The Arvi starch at 0.5% level increases the water holding capacity, and viscosity and lowers the syneresis problems in yogurt as compared to the control that contains gelatin (0.5%). The Arvi starch at the level of 0.5% gave the best results as it increased the acceptability, viscosity (1940-2365cp), and water holding capacity (29.30-30.50%) of yogurt. However, the sensory attributes were not affected significantly by the addition of Arvi starch at 0.5% level.

1. Introduction

Various polysaccharides are used in the food industry across numerous recipes, though some remain underexplored and have untapped potential for food applications. These sources of carbohydrates are either wild or cultivated plants that have many functional properties. Polysaccharides which are used for food production come from edible sources. Arvi or taro is a good source of starch. It is the thickened underground part of a stem that grows in Asia, Africa, North America, and other tropical regions worldwide. This part is typically referred to as the corm, which is rich in starch and serves as a popular root vegetable (Ubalua *et al.*, 2016). The shelf life

of corms is also low due to high water content. The main constituent of Arvi is starch which has been reported up to 80%. The size of the starch granules is also very small generally less than 10 µm. The mucilage content of Arvi starch is 9.1% in its crude form (Pachau *et al.*, 2018). The Arvi contains 70-80% digestible starch. The digestibility of Arvi starch is high because the granule size is very small as it is used in infant formulas and for gastric patients (Lovera *et al.*, 2017). Arvi has 63-85% moisture and due to high moisture content, it has high post-harvest losses. The protein content of Arvi ranges from 1-5%. It has been estimated that 30% of losses occurred during storage. Arvi storage in the

Corresponding Author: Umair Ali Email: umair.ali@iub.edu.pk

form of starch or flour is an excellent idea to reduce the losses. The stability of native Arvi starch would be increased due to the addition of pectin, polysaccharides, and stabilizers (Hussein *et al.*, 2010). Arvi is abundant in carbohydrates and serves as a less significant source of oils and fats. It is also rich in vitamins, including B1, B2, and B3, as well as important minerals such as phosphorus, magnesium, and zinc. Additionally, the corms of Arvi are recognized as an industrial source of starch and flour. (Aboubakar *et al.*, 2008).

Starch comprises a long chain of alpha-glucose units and is insoluble in water (Yazid *et al.*, 2018). Starch possesses several key properties that play an essential role in food applications, where it serves as a thickener, stabilizer, texture enhancer, gelling agent, and binding agent (Shaheryar *et al.*, 2023). Due to its small granule size and ease of digestion, this source's starch is suitable for infant formulas and gluten-free products (Nagar *et al.*, 2021). Yogurt is a healthy and nutritious human food, containing beneficial lactic acid bacteria (LAB). Because of the presence of these bacteria, yogurt is recognized as a probiotic product (Tan *et al.*, 2016). The quality of yogurt can be improved by maintaining its stability and consistency. Arvi starch is used as a stabilizer in yogurt, serving functions such as texture modification, enhancing appearance, and preventing syneresis. Key roles of stabilizers like Arvi starch include improving water-holding capacity and modifying texture to create a more consistent product. The activity of stabilizers is affected by composition, interaction with milk proteins, and rheological properties. It is considered that the digestibility of Arvi starch is comparable to corn starch. Arvi (taro) starch also contains antinutritional factors such as oxalates, which can cause a tingling or unpleasant sensation in the mouth (Kumar and Belur, 2018).

Achieving effective stabilization in yogurt is a significant challenge for the food industry today. Unlike conventional starches such as corn, potato, cassava, and rice starch, Arvi (taro) starch remains relatively under-researched, though interest in its potential applications has grown over time. The main aim of this study is to address these challenges and enhance the stability and sensory qualities of yogurt through the incorporation of Arvi starch.

2. Materials and Methods

2.1. Raw materials

Cow milk was collected from a dairy farm in Faisalabad, Pakistan, and stored under suitable conditions (under refrigeration) to prevent spoilage. Disease-free, healthy Arvi was sourced from the local market.

2.2. Yogurt starter culture

Yogurt culture, comprising *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, was obtained from the dairy laboratory at the National Institute of Food Science and Technology, University of Agriculture, Faisalabad, and preserved through freeze-drying (Tan *et al.*, 2016).

2.3. Extraction of starch

2.3.1. Extraction without chemicals

The arvi was washed with tap water and peeled before being dried in an oven at 50°C. The dried sample was then processed using a hammer mill and passed through a 500 µm screen. Arvi flour (100 g) was soaked in water for 12 hours. To homogenize the slurry, it was blended in a laboratory blender (model 51BL30) and subsequently screened through a sieve with a mesh size of 150 µm. The resulting crude starch was collected from the sediment after one day and oven-dried for further analysis (Oladebeye *et al.*, 2009; Aboubakar *et al.*, 2008).

2.3.2. Extraction with chemicals

In this method, chemicals such as sodium bisulfite and ethyl alcohol were utilized for the extraction process. The sample was washed and prepared for blending, which was performed using a sodium bisulfite solution (750 ml/L). Filtration was then carried out using 200 mesh sieves, with the residues rinsed in sodium bisulfite. The resulting filtrate was stored at 4°C for 12 hours. A 0.1% NaOH solution was used to facilitate the settling of starch particles before centrifugation, which was conducted at 6000 rpm. The centrifuged precipitate exhibited a pH close to neutral after the washing and drying processes, with ethyl alcohol also used for washing. Oven drying was employed to prevent damage to the starch during milling. The starch was then ground and passed through 200 mesh sieves. The Arvi starch powder was collected and stored in a dry place, with the starch samples properly wrapped in polythene bags for preservation (Sameen *et al.*, 2016; Hung *et al.*, 2010).

2.4. Analysis of starch

2.4.1. Ash, moisture and crude protein content

The moisture, protein, and ash content were determined using AOAC (2000) methods.

2.4.2. pH

The pH was measured with the help of a digital pH meter (WTW inoLab pH 720). The Starch sample (15 g) was mixed

with water and the electrode was immersed in it, providing a pH reading on the meter (Ali *et al.*, 2023).

2.4.3. Water holding capacity (WHC)

WHC was calculated by taking 1 g of Arvi starch and centrifuging it at 16000 rpm at room temperature for 10-15 minutes (Garg and Jana, 2011).

2.4.4. Swelling power and solubility

The starch sample (0.1 g) was dissolved in 20 ml of water for 2 minutes and then centrifuged at 3000×g for 15-20 minutes to assess its solubility behavior (Pachau et al., 2018; Garg and Jana, 2011). To determine the swelling power (SP) of the starch, 0.5-1 g of the starch sample was dissolved in 20 ml of distilled water in centrifuge tubes, which were then placed in a water bath at varying temperatures (60, 70, 80, and 90°C). The samples were centrifuged at 12000×g. The fluid floating on the surface was poured into a petri dish and dried in an oven at 105°C until all moisture was removed. An electrical digital balance was used to weigh the swollen starch granules (Sit et al., 2013).

% solubility = $\frac{\text{dried starch weight in petri dish}}{\text{weight of sample}} \times 100$

SP = $\frac{\text{weight of swollen granules}}{\text{weight of dry sample} \times (1 - \text{solubility})} \times 100$

2.4.5. Syneresis

The syneresis of starch was estimated by first heating the suspension at 85°C for 25 minutes followed by centrifuged at 3000 rpm for 20 minutes (Singh *et al.*, 2009).

2.4.6. Pasting properties

Pasting properties of starch were determined by using the RVA (Rapid Visco Analyzer). A 12 g of starch slurry was used for the determination of the viscosity profile. The heating and cooling cycles were used in which heating was done at 95°C. The sample was kept at this temperature for 2.5 minutes. Cooling of the sample was done, and the temperature was reduced to 95-50°C and the sample was kept at this temperature for 2 minutes (Sukhija *et al.*, 2016). RVA plotted the graph from which peak viscosity, hold viscosity, and final viscosity were recorded (Agama-Acevedo *et al.*, 2011).

2.5. Preparing yogurt

In preliminary trials, different concentrations of Arvi starch (0.1, 0.2, 0.3, 0.4, 0.5%) were used in yogurt but a 0.5% level was selected for further study to check its effects on yogurt properties. The starch at the concentration of 0.5%

(without chemicals and with chemicals extraction) was dissolved in a small amount of milk. Buffalo milk was heated at 90°C for 10 minutes and then the above mixture was dissolved in it (Krisnaningsih *et al.*, 2018). The purpose of heating was to improve the consistency of yogurt and reduce the expulsion of whey. Heating not only concentrated the milk but also effectively eliminated unwanted microorganisms, ensuring a safer and richer product. A bacterial starter culture of LAB (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*) was added in the milk. The incubation was carried out at 42°C for 2-3 hours. The yogurt was stored for 7 days in the refrigerator at 4°C and analyses were performed after 0, 7, and 15 days of storage (Hussein *et al.*, 2011).

Table 1. Treatment plan

Yogurt samples	Arvi starch	Gelatin
Gy	-	0.5%
Py	-	-
S ₁ Y ₁	0.5%	-
S ₂ Y ₂	0.5%	-

Gy= yogurt with 0.5% gelatin (control); Py= Plain yogurt (no stabilizer); S₁Y₁= Arvi starch at 0.5% level (extraction without chemicals); S₂Y₂= Arvi starch at 0.5% level (extraction with chemicals)

2.6. Analysis of yogurt

The yogurt chemical analysis was carried out by using AOAC (2005) methods. Yogurt was tested for its acidity pH, total solids, syneresis, viscosity and water holding capacity during 0 to 15 days of storage.

2.6.1. Acidity and pH

Titrateable acidity was calculated through the titration method using the 0.1N NaOH solution with a phenolphthalein indicator. pH was measured with the digital pH meter (WTW inoLab pH-720).

2.6.2. Viscosity

Brookfield DV-E viscometer was used to determine the viscosity of yogurt at 5-6°C (Aryana and McGrew, 2007).

2.6.3. Total solids

Total solids in yogurt were measured by following the AOAC (2000) method.

2.6.4. Syneresis and water holding capacity

Nafiseh *et al.* (2008) method was used to determine the syneresis of yogurt during different storage periods. Syneresis is the extraction/expulsion of the liquid from a gel. For the estimation of syneresis, the amount of separated whey was measured. After 30 minutes at room temperature, the amount of whey collected was assumed to be an index of

syneresis. Water holding capacity was determined by taking 10 g of yogurt sample and centrifuging it at 13000 rpm for 35 minutes (Spasenija *et al.*, 2007).

2.6.5. Sensory analysis

A panel of 5 trained experienced food and dairy technologists evaluated the sensory characteristics of yogurt and assigned scores for texture, appearance, sensory acidity, and flavor using 9-point hedonic scale.

2.7. Statistical analysis:

Complete Randomized Design (CRD) with a two-factor factorial was used for statistical analysis, and the analysis of variance technique was employed to estimate the level of significance. Means were further compared using Tukey's honest significance test. (Sameen *et al.*, 2016).

3. Results and Discussion

Starch extraction was performed using chemical and non-chemical methods, resulting in polysaccharides that were classified as ethanol-soluble (PS2) and ethanol-insoluble (PS1). The yield of PS1 was higher than that of PS2, measuring 19.5%. Upon complete analysis, the carbohydrate content was 82% for PS1 and 87.4% for PS2. Similarly, the soluble protein contents for both types were 3.5% for PS1 and 9.5% for PS2 (Table 2). These results indicate that the ethanol-soluble starch (extracted with chemicals) exhibited the highest yields of both carbohydrates and proteins. Our results were in line with Hussein *et al.*, (2011). The higher yield of ethanol-soluble polysaccharides (PS2) may be due to the chemical extraction process, which facilitates the dissolution of certain components, enhancing the solubility of carbohydrates and proteins in ethanol.

3.1. Physicochemical analysis of starch

The results of the physicochemical analysis of arvi starch are presented in Table 3. The values for pH, water holding capacity (WHC), swelling power, solubility, syneresis, ash

ranged from 5.6 to 5.7%, 82.45 to 83.40%, 12.0 to 12.2%, 4.30 to 4.40%, 28.4 to 29.0%, 0.12 to 0.14%, 10.0 to 10.5%, 0.5 to 0.6%, and 7452 to 7470 cp, respectively. These values are consistent with the findings of Kumar and Belur (2018) and Lovera *et al.* (2017). The results indicate no significant differences in starch characteristics, regardless of whether the extraction was performed with or without chemicals. This suggests that the extraction method may not significantly affect the fundamental physicochemical properties of arvi starch. (Sameen *et al.*, 2016).

3.2. Physicochemical analysis of yogurt

The results of the physicochemical analysis of yogurt are depicted in Table 4. The pH of yogurt was decreased during the 15 days of storage both in control and samples treated with Arvi (taro) starch. During the storage, disaccharide lactose sugar in milk was transferred to lactic acid and due to this conversion, pH decreased. The results of our findings regarding pH depicted that the control (plain yogurt Py) treatment showed a maximum decrease in pH (4.43-3.75) during storage and the Arvi starch-treated samples showed minimum decrease in pH ranges from 4.59-4.15 for S₁Y₁ (extraction without chemicals) and 4.62-4.15 S₂Y₂ (extraction with chemicals). This showed that arvi starch-treated sample could resist the pH reduction and made it acceptable even after storage. Our results about the pH reduction during storage are in line with the findings of Sameen *et al.* (2016) and Seelee *et al.* (2009).

However, the acidity of the yogurt increased during storage. The lactic acid bacteria convert the lactose sugar into lactic acid due to which acidity increases. In the present study, we found that plain yogurt (with no stabilizer) showed the maximum change in acidity (0.80-3.27) while the control (with 0.5% gelatin) and taro starch treatments (S₁Y₁ and S₂Y₂) had a minimum increase in acidity after storage. Their acidity values were in the range of 0.65-1.35 for control, 0.75-1.50

Table 2. Carbohydrate and soluble protein contents of polysaccharides (PS) extracted from taro.

Plant Source	Soluble Protein (%)		Carbohydrate (%)	
	PS1	PS2	PS1	PS2
<i>Colocasia esculenta</i>				
	(Ethanol insoluble)	(Ethanol soluble)	(Ethanol insoluble)	(Ethanol soluble)
	3.8±1.1	9.8±1.8	82±2.7	87.3±2.2

PS1=Ethanol insoluble polysaccharides

PS2=Ethanol soluble polysaccharides

content, moisture content, protein content, and viscosity

Table 3: Physicochemical analysis of starch extracted from arvi (*Colocasia esculenta*).

Physic-chemical analysis	Extraction with chemicals	Extraction without chemicals
pH	5.7±0.2	5.6±0.1
WHC (%)	82.45±1.2	83.40±1.5
Swelling Power	12.0±1.0	12.2±0.4
Solubility	4.30±0.3	4.40±0.5
Syneresis (%)	28.4±2.3	29.0±1.7
Ash content (%)	0.14±0.1	0.12±0.02
Moisture content (%)	9.9±1.3	10.0±0.8
Protein content (%)	0.6±0.01	0.5±0.05
Viscosity (cp)	7470±103	7452±89

WHC= water holding capacity

Table 4: Physicochemical analysis of yogurt during storage period

Treatments	Storage (Days)	pH	Acidity (%)	Total Solids (%)
Gy	0	4.72 ^a	0.65 ^{fg}	14.40 ^c
	7	4.50 ^c	1.00 ^{ef}	14.40 ^c
	15	4.25 ^{ef}	1.35 ^{cd}	14.42 ^c
Py	0	4.43 ^{cd}	0.80 ^f	12.50 ^h
	7	4.02 ^g	2.23 ^b	12.60 ^{gh}
	15	3.75 ^h	3.27 ^a	12.73 ^g
S ₁ y ₁	0	4.59 ^{bc}	0.75 ^{fg}	13.70 ^f
	7	4.28 ^e	1.13 ^f	13.98 ^e
	15	4.15 ^f	1.50 ^{cd}	14.20 ^d
S ₂ y ₂	0	4.62 ^b	0.75 ^{fg}	14.12 ^{de}
	7	4.40 ^d	1.60 ^c	14.59 ^b
	15	4.15 ^f	1.45 ^{cd}	14.75 ^a

Gy= yogurt with 0.5% gelatin (control)
Py= Plain yogurt (no stabilizer)
S₁y₁= Arvi starch at 0.5% level (extraction without chemicals)
S₂y₂= Arvi starch at 0.5% level (extraction with chemicals)

for S₁y₁, and 0.75-1.45 for S₂y₂. Our findings are per Krisnaningsih *et al.* (2017) and Andic *et al.* (2013) who demonstrated that yogurt acidity increased during storage.

There was a significant difference in the total solids during storage. The control treatment (Gy) exhibited non-significant variation in total solids, ranging from 14.40 to 14.42 %. Additionally, there is a significant difference (p<0.05) in total soluble solids across different treatments. The total solid contents in S₁y₁ and S₂y₂ were 13.70 and 14.12 respectively, before storage and significantly increased after storage i.e., 14.20 for S₁y₁ and 14.75 for S₂y₂. Our findings completely align with Sameen *et al.* (2016) who described that the total solid ratio was slightly increased due to an increase in syneresis. Both arvi starch and gelatin possess good water-holding capacity. Their ability to bind water can help maintain moisture levels, thus preventing a reduction in total solids due to evaporation or syneresis.

3.2.1. Viscosity, syneresis, and water holding capacity of yogurt

These properties of yogurt were affected significantly (p<0.05) by using stabilizers such as gelatin and arvi starch as well as during storage (Table 5). It is clear from Table 5 that the viscosity of all samples decreased from 1-7 days and increased from 7-15 days. The rearrangement of protein and protein-protein interaction was the main reason for increased viscosity during storage. The concentration of protein and fat, along with temperature, pH, and milk age, significantly affects viscosity during storage. Our findings showed that the control treatment (Gy) had the minimum decrease in viscosity (2230-2185 cp) and S₂y₂ had maximum decrease in viscosity after 15 days of storage (2365-2170 cp). These results are in line with Malik, (2012), Eissa *et al.* (2011), and Sameen *et al.* (2016) who demonstrated that the viscosity of

Table 5. Analysis of viscosity, syneresis and water holding capacity of yogurt during storage

Treatments	Storage (Days)	Viscosity (cp)	Syneresis (%)	WHC (%)
Gy	0	2230 ^b	1.80 ^f	12.95 ^c
	7	1980 ^d	2.00 ^f	11.50 ^{ef}
	15	2185 ^b	2.12 ^{ef}	10.30 ^f
Py	0	1300 ^g	3.25 ^c	10.50 ^f
	7	1035 ⁱ	5.02 ^b	8.60 ^g
	15	1215 ^h	6.50 ^a	6.99 ^h
S ₁ Y ₁	0	1940 ^d	2.10 ^{ef}	29.30 ^{ab}
	7	1667 ^f	2.70 ^d	27.40 ^c
	15	1800 ^e	2.95 ^{cd}	25.30 ^d
S ₂ Y ₂	0	2365 ^a	2.00 ^f	30.50 ^a
	7	2055 ^c	2.12 ^{ef}	28.90 ^{bc}
	15	2170 ^b	2.51 ^{de}	25.80 ^d

Gy= yogurt with 0.5% gelatin (control)

Py= Plain yogurt (no stabilizer)

S₁Y₁= Arvi starch at 0.5% level (extraction without chemicals)

S₂Y₂= Arvi starch at 0.5% level (extraction with chemicals)

**Figure 1:** Effect of treatments and storage on organoleptic evaluation of yogurt

yogurt decreased during the storage due to an increase in acidity. The viscosity of yogurt developed with taro starch and gelatin decreases during storage primarily due to syneresis, where liquid whey separates from the gel structure and structural breakdown of the starch and gelatin network caused by enzymatic activity and microbial action. These factors lead to a loss of thickness and stability over time.

The syneresis in yogurt increased significantly ($p < 0.05$) after 15 days of storage (Table 5). The results of our findings regarding syneresis of yogurt depicted that treatment Py had a significant increase in syneresis while the control treatment and arvi starch treatments showed minimum increase in

syneresis. The syneresis amount in plain yogurt (Py) increased from 3.25-6.50, 2.10-2.95 in S₁Y₁ and 2.0-2.51 in S₂Y₂ respectively. Our findings aligned with those of Hussein *et al.* (2011) and Sakandar *et al.* (2014), who reported a similar trend regarding syneresis. Syneresis in yogurt developed with taro starch and gelatin increases during storage due to the destabilization of the gel network, which can occur from moisture loss, enzymatic activity, and microbial growth. These factors lead to the separation of the whey, resulting in increased liquid expulsion over time.

Water holding capacity of yogurt was decreased by increasing the storage time (Table 5). It is clear from the table

that water holding capacity of all samples decreased significantly after 15 days of storage due to increased syneresis. When lactose is converted to lactic acid, an interaction occurs between casein and polysaccharides which was the main cause of the reduction in WHC of yogurt during storage (J.D. Hoyos-Leyva *et al.*, 2018). Our findings regarding the WHC depicted that the sample treated with arvi starch had a maximum water holding capacity of 29.30-25.30% for S_{1Y1} and 30.50-25.80% for S_{2Y2} which is much higher as compared to control (Gy) and plain yogurt (Py). These findings are like Sameen *et al.* (2016) and Sakandar *et al.* (2014) who demonstrated that acidity and syneresis increased during storage due to which water holding capacity decreased.

3.2.2 Sensory evaluation

As shown in Fig. 1, the incorporation of arvi starch in yogurt had no significant effect on sensory characteristics. Sensory scores of the yogurt decreased over the storage period from day 0 to day 15, with overall acceptability declining over time. The largest decrease in acceptability was observed in plain yogurt, dropping from 6.00 to 4.00, followed by S_{1Y1} and S_{2Y2}, which declined from 8.00 to 6.00 and 8.00 to 5.00, respectively. The control treatment (Gy) showed the smallest decline, from 8.00 to 7.00. These findings are consistent with Sameen *et al.* (2016) and Salwa *et al.* (2004).

The sensory evaluation results show that the control treatment (Gy) maintained the highest scores across appearance, flavor, and texture over 15 days, with minimal decline. Plain yogurt (Py) showed the greatest decrease, particularly in appearance (dropping from 7 to 4) and texture (6 to 4). For the treatments with arvi starch (S_{1Y1} and S_{2Y2}), sensory scores were more stable, especially for S_{1Y1}, which retained higher scores across all attributes over time compared to S_{2Y2}. This indicates that arvi starch may contribute to maintaining sensory quality, with S_{1Y1} performing slightly better than S_{2Y2}.

4. Conclusion

The use of stabilizers greatly improves yogurt formation by enhancing stability, viscosity, texture, mouthfeel, and minimizing syneresis. Among the treatments, using 0.5% arvi starch yielded optimal results, providing superior texture and stability. This formulation also supports yogurt storage for up

to 15 days at refrigerated temperatures, maintaining desirable quality and sensory characteristics over time.

5. Funding

No funding was received for this study.

6. Acknowledgment

The authors are grateful to the University of Agriculture Faisalabad for providing chemicals for the research.

7. Conflict of Interest

The authors declare no conflict of interest.

8. Authors' Contribution

Umair Ali: Conceptualization, Methodology, Software; Hammad Hafeez: Data curation, Writing - Original draft preparation; Talha Hafeez: Visualization, Investigation; Amara Shafqat: Writing - Reviewing and Editing; Areej Nasir: Software, Validation.

References

- Aboubakar, A., Njintang, Y. N., Scher, J., & Mbofung, C. M. F. (2008). Physicochemical, thermal properties and microstructure of six varieties of taro (*Colocasia esculenta* L.) flours and starches. *Journal of food Engineering*, 86(2), 294-305.
- Agama-Acevedo, E., Garcia-Suarez, F. J., Gutierrez-Meraz, F., Sanchez-Rivera, M. M., San Martin, E., & Bello-Perez, L. A. (2011). Isolation and partial characterization of Mexican taro (*Colocasia esculenta* L.) starch. *Starch Starke*, 63(3), 139-146.
- Ali, U., Saeed, M., Ahmad, Z., Shah, F. U. H., Rehman, M. A., Mehmood, T., Waseem, M., Hafeez, H., Azam A., & Rahman, A. (2023). Stability and survivability of alginate gum-coated *Lactobacillus rhamnosus* GG in simulated gastrointestinal conditions and probiotic juice development. *Journal of Food Quality*, 2023(1), 1-13.
- Andiç, S., Boran, G., & Tunçtürk, Y. (2013). Effects of carboxyl methyl cellulose and edible cow gelatin on physico-chemical, textural and sensory properties of yogurt. *International Journal of Agriculture & Biology*, 15(2), 112-124.
- AOAC. (2019). *Official methods of analysis* (17th ed.). The Association of Official Analytical Chemists.
- AOAC. (2005). *Official Methods of Analysis*. The Association of Official Analytical Chemists.
- Aryana, K. J., & McGrew, P. (2007). Quality attributes of yogurt with *Lactobacillus casei* and various prebiotics. *LWT-Food Science and Technology*, 40(10), 1808-1814.

- Eissa, E. A., Babiker, E. E., & Yagoub, A. E. A. (2010). Physicochemical, microbiological and sensory properties of Sudanese yogurt (zabadi) made from goat's milk. *Animal Production Science*, 51(1), 53-59.
- Garg, S., & Jana, A. K. (2011). Characterization and evaluation of acylated starch with different acyl groups and degrees of substitution. *Carbohydrate Polymers*, 83(4), 1623-1630.
- Huang, C. C., Lai, P., Chen, I. H., Liu, Y. F., & Wang, C. C. (2010). Effects of mucilage on the thermal and pasting properties of yam, taro, and sweet potato starches. *LWT-Food Science and Technology*, 43(6), 849-855.
- Hussein, M. M., Hassan, F. A., Daym, H. A., Salama, A., Enab, A. K., & Abd El-Galil, A. A. (2011). Utilization of some plant polysaccharides for improving yogurt consistency. *Annals of Agricultural Sciences*, 56(2), 97-103.
- Krisnaningsih, A. T. N., Yulianti, D. L., Thohari, I., & Surjowardojo, P. (2017). Optimization of yogurt fermented milk products with the addition of natural stabilizer based on local potential of taro starch (*Colocasia esculenta*). *UNEJ e-Proceeding*, 1(1), 77-79.
- Kumar, K., & Belur, P. D. (2018). A novel enzymatic process to produce oxalate depleted starch from taro. *Starch Starke*, 70(11-12), 170-183.
- Lovera, M., Perez, E., & Laurentin, A. (2017). Digestibility of starches isolated from stem and root tubers of arracacha, cassava, cush-cush yam, potato and taro. *Carbohydrate polymers*, 176(1), 50-55.
- Malik, A. H., Faqir, M., Ayesha, S., Muhammad, I., & Muhammad, S. (2012). Extraction of starch from Water Chestnut (*Trapa bispinosa* Roxb) and its application in yogurt as a stabilizer. *Pakistan Journal of Food Science*, 22(4), 209-218.
- Vahedi, N., Tehrani, M. M., & Shahidi, F. (2008). Optimizing of fruit yoghurt formulation and evaluating its quality during storage. *American-Eurasian Journal of Agricultural & Environmental Science*, 3(6), 922-927.
- Nagar, C. K., Dash, S. K., Rayaguru, K., Pal, U. S., & Nedunchezhiyan, M. (2021). Isolation, characterization, modification and uses of taro starch: A review. *International Journal of Biological Macromolecules*, 192(1), 574-589.
- Oladebeye, A. O., Oshodi, A. A., & Oladebeye, A. A. (2009). Physicochemical properties of starches of sweet potato (*Ipomea batata*) and red cocoyam (*Colocasia esculenta*) cormels. *Pakistan Journal of Nutrition*, 8(4), 313-315.
- Öztürk, G., Azeri, F. N., & Yıldırım, Z. (2012). Field performance of in vitro sweet potato [*Ipomoea batatas* L. (Lam)] plantlets derived from seedstocks. *Turkish Journal of Field Crops*, 17(1), 1-4.
- Pachua, L., Dutta, R. S., Devi, T. B., Deka, D., & Hauzel, L. (2018). Taro starch (*Colocasia esculenta*) and citric acid modified taro starch as tablet disintegrating agents. *International Journal of Biological Macromolecules*, 118(1), 397-405.
- Sakandar, H. A., Imran, M., Huma, N., Ahmad, S., Aslam, H. K. W., Azam, M., & Shoaib, M. (2014). Effects of polymerized whey proteins isolates on the quality of stirred yogurt made from camel milk. *Journal of Food Processing & Technology*, 5(7), 1-14.
- Salwa, A. A., Galal, E. A., & Neimat, A. E. (2004). Carrot yogurt: Sensory, chemical, microbiological properties and consumer acceptance. *Pakistan Journal of Nutrition*, 3(6), 322-330.
- Sameen, A., Khan, M. I., Sattar, M. U., Javid, A., & Ayub, A. (2016). Quality evaluation of yogurt stabilized with sweet potato (*Ipomoea batatas*) and taro (*Colocasia esculenta*) starch. *International Journal of Food and Allied Sciences*, 2(1), 23-29.
- Seelee, W., Tungjaroenchai, W., & Natvaratat, M. (2009). Development of low-fat set-type probiotic yoghurt from goat milk. *Asian Journal of Food and Agro-Industry*, 2(4), 771-779.
- Simsek, S., & El, S. N. (2012). Production of resistant starch from taro (*Colocasia esculenta* L. Schott) corm and determination of its effects on health by in vitro methods. *Carbohydrate polymers*, 90(3), 1204-1209.
- Simsek, S., & El, S. N. (2015). In vitro starch digestibility, estimated glycemic index and antioxidant potential of taro (*Colocasia esculenta* L. Schott) corm. *Food Chemistry*, 168(1), 257-261.
- Singh, G. D., Bawa, A. S., Singh, S., & Saxena, D. C. (2009). Physicochemical, pasting, thermal and morphological characteristics of Indian water chestnut (*Trapa natans*) starch. *Starch Starke*, 61(1), 35-42.
- Sit, N., Misra, S., & Deka, S. C. (2014). Characterization of physicochemical, functional, textural and color properties of starches from two different varieties of taro and their comparison to potato and rice starches. *Food Science and Technology Research*, 20(2), 357-365.
- Sukhija, S., Singh, S., & Riar, C. S. (2016). Isolation of starches from different tubers and study of their physicochemical, thermal, rheological and morphological characteristics. *Starch Starke*, 68(1-2), 160-168.
- Spasenija, D., M. Caric, S. U. Mirela, D. Ilicic, and G. D. Katarina. 2007. Physio-chemical properties of probiotic yogurt produced with transglutaminase. *International Dairy Journal*, 38(1), 11-19.
- Shaheryar, M., M. Afzaal, F. Nosheen, A. Imran, F. Islam, R. Noreen, and Rasool, A. (2023). Functional exploration

- of taro starch (*Colocasia esculenta*) supplemented yogurt. *Food Science & Nutrition*, 11(6), 2697-2707.
- Tan, H. A. D., E. I. Dizon, V. L. Barraquio and S. M. Mercado. 2016. Efficacy of alginate-taro (*Colocasia esculenta* L.) starch for yogurt starter culture encapsulation. *Journal of Science, Engineering and Technology*. 4(1), 1-10.
- Ubalua, A. O., F. Ewa and O. D. Okeagu. 2016. Potentials and challenges of sustainable taro (*Colocasia esculenta*) production in Nigeria. *Journal of Applied Biology and Biotechnology*. 4(1), 53-59.
- Yazid, N. S. M., N. Abdullah, N. Muhammad and H. M. Matias-Peralta. 2018. Application of Starch and Starch-Based Products in Food Industry. *Journal of Science and Technology*. 10(2), 144-174.

Disclaimer/Publisher's Note: The views, opinions, and data presented in all publications are exclusively those of the respective author(s) and contributor(s) and do not reflect the stance of Pagepal or its editorial team. Pagepal and the editor(s) disclaim any responsibility for harm to individuals or damage to property resulting from the use of any ideas, techniques, instructions, or products mentioned in the content.