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Formulation and Quality Evaluation of Spray-dried Bignay Vinegar Adjunct With Maltodextrin

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Abstract

Objective: The food industry widely employs the production of powdered vinegar from fruit by-products. The present investigation evaluated the percent recovery and physico-chemical properties of Bignay vinegar, mixed with varying concentrations of maltodextrin obtained through spray drying. **Methods:** Three formulations were prepared, with three samples per replication. Analysis of Variance (ANOVA) was employed to evaluate disparities among the means, while Least Significant Differences (LSD) were employed to determine significant mean differences at 0.01 and 0.05 significance levels. **Findings:** The percent recovery of the different formulations ranged from 68.7% to 80.4%. Consumer-based sensory evaluation revealed that the formulated Bignay vinegar powder exhibited significant acceptability concerning its aroma, taste, and general acceptability. The powdered vinegar, with the most acceptable formulation, had a pH of 3.27 at 20.6°C, total soluble solids of 98°, and titratable acidity as acetic acid of 3.03%. The proximate analysis demonstrated low concentrations of ash (0.26%), crude fat (less than 0.10%), and crude protein (0.75%), with negligible calories from fat (less than 0.009 kcal/g) and calories from protein (0.03 kcal/g), along with a moisture content of 7.26%. However, it exhibited high total carbohydrates (9.73%), calories from carbohydrates (3.67 kcal/g), and total calories (3.70 kcal/g). The Bignay vinegar with 30% added carrier exhibited the highest percent recovery, highly acceptable sensory quality, and typical acidity for food vinegar. **Novelty:** The formulated Bignay vinegar powder provides consumers with the opportunity to enjoy the taste of vinegar, even when the Bignay fruiting season is over.

Keywords: Spray-drying; Bignay vinegar; Maltodextrin; Percent Recovery; Physicochemical Properties

1 Introduction

Vinegar is highly valued as an acidic condiment and food preservative across the globe[1]. It is extensively utilized in the food service and catering sectors, where it plays an indispensable role in numerous culinary applications [2]. This versatile ingredient is a key component in many dishes, including marinades, salad dressings, pickles, sauces, and other condiments, where it imparts a distinctive flavor.

Fruit vinegar is becoming increasingly popular due to its numerous health benefits. These include weight loss, blood glucose reduction for non-insulin-dependent diabetes mellitus patients, antioxidant properties, heart disease prevention, and post-physical activity revitalization [3].

Addressing the issue of post-harvest fruit losses is crucial in the province. Particularly in Sanchez Mira, Cagayan, Philippines, an abundance of local berries, notably Bignay (*Antidesma bunius* (L.) Spreng.) fruits, goes to waste due to their relatively low market value as table fruit. Although these fruits can be consumed raw, a substantial quantity remains unutilized, left to rot on the ground until they are disposed of as waste. One effective way to reduce this waste is by turning surplus fruits into vinegar, which offers a practical solution. This approach allows for preserving certain foods and snacks while reducing losses. The food industry widely adopts this option to utilize excess and imperfect fruits, maintaining the integrity of the final product [4]. Bignay fruits are recognized for their potential in vinegar production, with Bignay vinegar gaining popularity for its remarkable antioxidant activities [5].

Traditionally, Bignay vinegar, like other types of vinegar, is made through a two-step fermentation process using raw materials, including grains, fruits, and vegetables. The process begins with the production of ethanol, which then undergoes fermentation to form acetic acid [2]. Liquid vinegar can be stored for an extended period in a glass bottle. However, its quality deteriorates if not used immediately after opening.

Recently, there have been significant advancements in fruit vinegar research. More researchers are now working on creating powdered vinegar as a substitute for liquid vinegar. For example, powdered vinegar from nipa (*Nypa fruticans*) was developed due to the impracticality of using liquid vinegar [6].Likewise, the production of powdered vinegar from nipa palm was improved through spray-drying, considering variables such as inlet temperature and maltodextrin concentration [7].Coconut water vinegar was also converted into powder using a spray dryer, with maltodextrin added as a stabilizer [8].Similarly, the potential of using nipa palm to create powdered vinegar was further explored [7].This innovation aimed to increase the availability of vinegar products in the market and meet the growing demand from industries.

While there have been some studies on drying fruit juice, a significant gap is evident in the literature concerning the production of Bignay vinegar powder. Therefore, the main goal of this research is to explore the potential of creating Bignay vinegar powder using spray drying techniques. The transformation of vinegar into a powder not only enhances the quality of the product by lowering its water content, but it also prolongs its shelf life, enhances storage capabilities, decreases packaging needs, and reduces transportation weight [7].

The success of this research would contribute to the diversification of Bignay fruit products, enhance productivity, create new market opportunities, and increase the income of smallholder farmers and cottage industry owners.

2 Methodology

2.1 Experimental Design

The study utilized a complete randomized design (CRD), examining three formulations replicated three times, with three samples in each replication. To determine significant differences between the formulations, an Analysis of Variance (ANOVA) was conducted on the collected data. Furthermore, the least significant differences (LSD) method was employed to identify which formulation means exhibited significant variations at the 0.01 and 0.05 significance levels.

2.2 Sources of Bignay Vinegar

The Bignay vinegar was obtained at the Food Processing Center of the Cagayan State University-Sanchez Mira Campus in Cagayan, Philippines. Two stages of fermentation are used to generate the vinegar. Firstly, alcoholic fermentation occurs, during which yeast, typically Saccharomyces species, converts fermentable sugars into ethyl alcohol and carbon dioxide. Subsequently, acetic fermentation occurs, where bacteria, commonly Acetobacter species, convert alcohol into acetic acid.

2.3 Product Preparation

The Bignay vinegar underwent an initial assessment of its pH, Total Soluble Solids (TSS), and total acid levels before the product formulation and spray drying process.

2.4 Product Formulation and Spray Drying

Ten liters of Bignay vinegar were mixed with maltodextrin according to the specified amounts in the formulations. For each sample, three formulations (with 30%, 40%, and 50% added carrier) were prepared before subjecting the Bignay vinegar to spray drying using a single-process schedule design.

The formulation of the powdered vinegar is shown in Table 1.

Table 1. Formulations of Coconut V inegar

	Formulation 1	Formulation 2	Formulation 3
Added carrier	30%	40%	50%
Inlet temperature	180°C	180°C	180°C
Outlet temperature	95°C	95°C	95°C
Pressure setting	40 psi	40 psi	40 psi

2.5 Percent Recovery

The percent recovery was determined by using the starting and ending weights of the vinegar. It was obtained by computing the percentage of the starting material that was recovered following the completion of a chemical process. The combined weight of the powder from the drying chamber and the cyclone makes up the overall weight of the powders.

2.6 Sensory evaluation

To evaluate the acceptability of the vinegar powder, a consumer evaluation test was conducted with a sample size of 50 target consumers, including both males and females aged between 15 and 60 years. The participants included students and staff from CSU-Sanchez Mira. Before rating the products, the panelists underwent an allergy test, and their consent was obtained following ethical procedures.

The evaluation took place in a room maintained at a temperature between 22°C and 24°C from 10:00 A.M. to 11:30 A.M., with white lighting. The vinegar powder underwent assessment for aroma, taste, appearance, and overall acceptability using a 9-point Hedonic scale. This scale ranged from 1 (least desired characteristic) to 9 (most preferred characteristic).

It is important to note that this evaluation does not directly represent consumer perception. However, it provides insights into the attributes of a high-quality product[(9)].

2.7 PH

The pH of the vinegar was measured following the procedure provided by the Association of Official Analytical Chemists[(10)]. Ten grams of vinegar were precisely measured and combined with 100 ml of distilled water in a beaker. The mixture was then centrifuged at 200 rpm for 20 minutes. After centrifugation, the liquid on top was poured off, and the pH was measured using a pH meter[(10)].

2.8 Titratable Acidity

The acid content of the vinegar was tested using an automatic titration machine from Radiometer Copenhagen. The total acidity was determined through titration with 0.5N NaOH, following the procedures outlined in the 21st edition (2019) of the Official Methods of Analysis from the Association of Official Analytical Chemists (AOAC), using method 932.12. For accuracy, each sample was tested three times, with three separate titration readings recorded for each[(10)].

2.9 Total Soluble Solids

Using a handheld Atago Brix refractometer, the total soluble solids (TSS) of the samples were determined. For each measurement, two to three drops of the sample were carefully applied to the prism of the refractometer. The TSS reading, expressed in °Brix, was recorded as the result. This process adhered to the instructions provided in the 21st edition (2019) of the Official Methods of Analysis by the Association of Official Analytical Chemists (AOAC) 932.12[(10)].

2.10 Proximate Analysis

The laboratory of SGS Philippines, Inc. conducted a proximate analysis to determine the nutritional composition of the samples. The ash and moisture content were measured using the Gravimetric method, which involves weighing the residue after combustion and the weight loss after drying, respectively. To analyze the crude fat content, acid hydrolysis and Gravimetric methods were used, while the Kjeldahl method was employed to determine protein content. Nutritional values, such as calories from carbohydrates, fat, and protein, as well as total calories and carbohydrates, were calculated using the 2019 Philippine Food Composition Tables. These tables offer comprehensive information on the nutritional makeup of different types of food.

3 Results and Discussion

3.1 Percent Recovery

Table 2 shows the range of percent recovery seen in different formulations, along with their average and standard deviation values. Recovery percentages varied from 68.7% to 80.4%, indicating that the amount of carrier added to the feed solution during spray drying affected the outcomes. It was observed that formulations with higher carrier concentrations had higher recovery rates. For instance, the formulation containing 50% maltodextrin had the highest recovery rate of 80.4%. In comparison, the formulation with 40% added carrier had a recovery rate of 75.1%. On the other hand, the formulation with the lowest carrier concentration of 30% had a recovery rate of 68.7%.

This research explains that the unique physical properties of powdered vinegar are due to differences in molecular weight and molecule type found in the added carrier. This result highlights that the unique physical properties of powdered vinegar are attributed to variations in molecular weight and the type of molecules present in the added carrier. These findings align with previous studies[11,12], which also demonstrated that increasing the concentration of maltodextrin leads to higher quantities of dried powder. Furthermore, this emphasizes the significant impact of maltodextrin concentration on production yield[13]. It is important to note the strong connection between the amount of carrier material and the recovery percentage, which is largely due to the carrier's ability to encapsulate active compounds effectively. By using higher levels of maltodextrin, the active ingredients likely received better protection during the drying process, leading to improved recovery rates. This underscores the need to carefully optimize the concentration of carrier material in spray-drying formulations to achieve the desired product quality and yield.

Table 2. Percent recovery of spray-dried Bignay vinegar in three formulations

Formulation	Recovery Percentage
Formulation 1	68.7 ± 1.0
Formulation 2	75.1 ± 0.91
Formulation 3	80.4 ± 1.42

Key: F_1_30% added carrier; F_2 _40% added carrier; F_3_00% added carrier

3.2 Sensory Characteristics of the Formulated Bignay Vinegar Powder

Based on the sensory evaluations in Table 3, Formulation 1 with 30% additional carrier had the most potent aroma rating among the samples.

The formulations with 40% and 50% added carrier had a similar and pleasant smell, but their combined scores were lower than Formulation 1. Formulations containing more than 30% added carrier appeared to have diminished the vinegar-like aroma of the product. This observation corroborates the findings that lower concentrations of maltodextrin result in a more intense vinegary odor, due to higher acetic acid content[7].

Regarding taste, the formulation with 30% added carrier was the most acceptable. The taste of the product was notably affected by the inclusion of maltodextrin. Notably, as the concentration of the carrier agent increased, the taste preference score decreased. These findings align with previous research, which demonstrated that reducing the quantity of added carrier in nipa vinegar helps retain more sensory characteristics, including flavor[6].

In terms of color, the formulation with the highest level of maltodextrin produced the lightest color compared to the other formulations. Since maltodextrin is a white powder, increasing its concentration correlates with a reduction in the color intensity of the powder, resulting in a pale shade when mixed with the original Bignay vinegar. Similar findings have been reported in the freeze-dried Andean Blueberry Juice powder[12], and microwave-assisted jackfruit juice powder[14].

However, upon conducting multiple comparisons among the formulation means, no significant difference in color liking ratings was observed in the consumer test. This finding suggests that adding maltodextrin to the liquid vinegar had no impact on this attribute.

The data also reveal the influence of varying maltodextrin levels on the overall acceptability of Bignay vinegar powder. The trend of the overall liking score closely matched that of aroma acceptability. Formulation 1 (30% added carrier) obtained the highest score of 7.40, indicating "like very much." However, statistical analysis indicates that both formulations with 40% and 50% added carriers received comparable ratings. Increasing the carrier beyond 30% tended to decrease the level of acceptability. Overall, the formulation with 30% added carrier consistently achieved a mean liking score greater than 7.30 across all parameters, indicating highly acceptable sensory quality. A product receiving this score can confidently be considered a good measure of target quality[15].

Table 3. Sensory characteristics of the formulated Bignay vinegar powder

Formulation	Aroma/Smell	Taste/Flavor	Color	General Acceptability
Formulation 1	8.06^a	8.20^a	8.38	7.40^a
Formulation 2	6.54^b	6.88^b	7.42	5.94^b
Formulation 3	6.20^b	5.58^c	6.80	5.74^b

Values with different superscript letters on the same columns are significantly different (p<.05) based on ANOVA with LSD test.

Key: F_1 _30% added carrier; F_2 _40% added carrier; F_3 _50% added carrier

3.3 PH, Total Soluble Solids, and Titratable Acidity

As seen in Table 4, the pH level of Bignay vinegar liquid is recorded to be 2.71, which is lower than the vinegar with added carrier (pH 3.27). However, the pH of Bignay powdered vinegar is comparable to bitter kola (pH 2.6–2.9) but lower than that of jackfruit with peel (pH 3.20–3.73) and jackfruit without peel (pH 3.20–3.40), as reported[16]. A lower pH indicates higher acidity in vinegar. The change in the acidity of Bignay vinegar powder is a consequence of the added carrier. A similar observation was made in spray-dried Nipa vinegar powder[6] and spray-dried mandarin (Citrus unshiu) beverage powder[17], where the acidity of the powdered product decreased with the addition of maltodextrin.

Total Soluble Solids (TSS) significantly increased in the formulation containing maltodextrin as the drying agent compared to Bignay vinegar liquid. This is because maltodextrin acts as a filler[18], increasing the total amount of soluble solids in the preparation[19]. Bignay vinegar liquid, which has a titratable acidity of 6.28%, has a similar strength to balsamic vinegar. This acidity level is typical for food vinegar and can be used in various applications, including cooking and canning[20].

On the other hand, Bignay vinegar powder, with a titratable acidity of 3.03%, is less acidic than most vinegar types. It offers a sweet, delicate flavor and is suitable for basic cooking and salad dressings.

Table 4. pH, Total Soluble Solids, and Titratable Acidity of Bignay Vinegar liquid compared to a Bignay Vinegar Powder with the most acceptable Formulation

Analysis Name	Bignay Vinegar liquid	Bignay Vinegar Powder
Ph	2.71 at 20.7°C	3.27 at 20.6°C
Total Soluble Solids	16.4°	98°
Titratable acidity as Acetic Acid	6.28%	3.03%

3.4 Proximate Analysis

Table 5 indicates that the vinegar powder sample possesses a low ash content of 0.26%, indicating a minute quantity of minerals. This finding aligns with a report, which states that plain, white vinegar does not provide significant vitamins or minerals, even with increased consumption[21].

The analysis shows that the vinegar powder has a very low crude fat content (<0.10%), meaning it is a low-fat ingredient. This makes it a healthier option for various applications.

Additionally, the sample contains only 0.75% crude protein, indicating that the vinegar powder is low in protein. This makes it a suitable choice for those looking to manage their weight, as it can help reduce overall food intake.

With a moisture content of 7.26%, the sample is well below the threshold for microbial growth in various types of flour, which is typically under 14.5% [22]. Foods with low moisture content are less susceptible to spoilage and the growth of harmful pathogens, contributing to a longer shelf life for packaged products [23].

The spray-dried vinegar powder sample contributes 3.70 calories per gram, considering calories from carbohydrates (3.69/g), fat (< 0.009/g), and protein (0.03/g). As a result, the powder provides a quick energy boost, making it a popular ingredient in packaged foods. This is especially beneficial for individuals needing to restore their blood sugar levels after intense exercise.

Typically, liquid vinegar contains a negligible amount of carbohydrates. However, due to the added carrier maltodextrin, the total carbohydrate content of the Bignay vinegar powder is relatively high at 9.73%. Maltodextrin is a carbohydrate, specifically a polysaccharide, but it is easily digestible and quickly provides a source of energy [24].

Table 5. Proximate analysis of Bignay vinegar powder

Analysis Names	Result	Methodology
Ash	0.26 %	Gravimetric Method (QLY-LAB-1153 REV1)
Crude Fat	< 0.10 %	Acid Hydrolysis and Gravimetric Method (QLY-LAB-1147 REV2)
Crude Protein (N X 6.25)	0.75 %	Kjeldahl Method (QLY-LAB-1201 REV1)
Moisture	7.26 %	Gravimetric Method (QLY-LAB-1202 REV0)
Calories from Carbohydrates	3.67 kcal/g	By Computation from Proximate Analysis (Philippine Food Composition Tables 2019)
Calories from Fat	< 0.009 kcal/g	By Computation from Proximate Analysis (Philippine Food Composition Tables 2019)
Calories from Protein	0.03 kcal/g	By Computation from Proximate Analysis (Philippine Food Composition Tables 2019)
Total Calories	3.70 kcal/g	By Computation from Proximate Analysis (Philippine Food Composition Tables 2019)
Total Carbohydrates	9.73 %	By Computation from Proximate Analysis (Philippine Food Composition Tables 2019)

4 Conclusion

The development of Bignay vinegar powder using the spray drying technique shows promise as a potential solution for reducing post-harvest losses of Bignay fruits while also promoting increased consumption of the product. This innovative powder opens up opportunities to create novel and unique food products. In the process of preparing and producing Bignay vinegar powder, the formulation with the highest added carrier yields the highest percentage of recovery. Sensory evaluations indicate that the powdered Bignay vinegar is well-received in terms of taste and other sensory characteristics, indicating a significant potential for commercial success.

From a nutritional standpoint, Bignay vinegar powder serves as an ideal ingredient for flavoring foods while promoting weight loss. It contains a significant amount of carbohydrates and total calories, making it a handy source of instant energy. Furthermore, its flavor strength is similar to traditional salad vinegar, increasing its versatility in various culinary uses.

Recommendation

The development of Bignay vinegar powder offers an exciting opportunity for creating innovative and distinctive food and cosmetic products. Testing consumer acceptance with various food options can gauge the market potential of the product. To guarantee the longevity of the spray-dried Bignay vinegar, it is crucial to thoroughly analyze the stability of the powder. This analysis will offer important information on preserving the quality of the product and prolonging its shelf life. By assessing the stability of the vinegar powder, any issues can be addressed, and storage conditions optimized to enhance the overall product quality and market competitiveness.

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References

1) Zhang XL, Zheng Y, Xia ML, Wu YN, Liu XJ, Xie SK, et al. Knowledge domain and emerging trends in vinegar research: A bibliometric review of the 214 literature from WoSCC. *Foods*. 2020;9(2):1–34. Available from: https://doi.org/10.3390/foods9020166.
2) Chen GL, Zheng FJ, Lin B, Yang YX, Fang XC, Verma KK. Vinegar: A potential source of healthy and functional food with special reference to sugarcane vinegar. *Frontiers in Nutrition*. 2023;10:1–10. Available from: https://doi.org/10.3389/fnut.2023.1145862.

3) Perumpuli B, Dilrukshi N. Vinegar: A functional ingredient for human health. *International Food Research Journal*. 2022;29(5):959–974. Available from: http://www.ifrj.upm.edu.my/29%20(05)%202022/01%20-%20IFRJ21100.R1%20(Review).pdf.
4) Luzón-Quintana LM, Castro R, Guerrero ED. Biotechnological processes in fruit vinegar production. *Foods* . 2021;10(5):1–23. Available from: https://doi.org/10.3390/foods10050945.
5) Hardinasinta G, Mursalim M, Muhidong J, Salengke S. Determination of some chemical compounds of bignay (*Antidesma bunius*) fruit juice. *Food Science and Technology*. 2021;41(4):974–979. Available from: https://doi.org/10.1590/fst.27720.
6) de Castro MA. Development and evaluation of Nipa (*Nypa fruticans*) vinegar powder. *JPAIR Multidisciplinary Research*. 2018;32(1):110–123. Available from: https://doi.org/10.7719/jpair.v32i1.578.
7) Palachum W, Klangbud WK, Chisti Y. Spray-dried Nipa Palm vinegar powder: Production and evaluation of physicochemical, nutritional, sensory, and storage aspects. *Fermentation* . 2022;8(6):1–13. Available from: https://doi.org/10.3390/fermentation8060272.
8) Hidayati I, Miskiyah J. Antimicrobial activity of coconut water vinegar powder to *Staphylococcus aureus*, *Escherichia coli* and *Candida albicans. IOP Conference Series: Earth and Environmental Science*. 2022;1024:12069–12069. Available from: https://doi.org/10.1088/1755-1315/1024/1/012069.
9) Akhter MJ, Hosain MM, Halim MA, Prabin M, Parvin S, Siddika A, et al. Consumer acceptance and physicochemical properties of developed Carambola (*Averrhoa carambola*) candy. *World Journal of Engineering and Technology*. 2022;10(2):458–471. Available from: https://www.researchgate. net/publication/361068179_Consumer_Acceptance_and_Physicochemical_Properties_of_Developed_Carambola_Averrhoa_carambola_Candy.
10) Latimer GW. Official methods of analysis of AOAC International. 22nd ed. Rockville, Md. AOAC International. 2019. Available from: https: //www.aoac.org/official-methods-of-analysis/.
11) Leyva-Porras C, Saavedra-Leos MZ, Cervantes-González E, Aguirre-Bañuelos P, Silva-Cázarez MB, Álvarez Salas C. Spray drying of Blueberry juice maltodextrin mixtures: Evaluation of processing conditions on content of resveratrol. *Antioxidants*. 2019;8(10). Available from: https://doi.org/10.3390/antiox8100437.
12) Estupiñan-Amaya M, Fuenmayor CA, López-Córdoba A. New Freeze-Dried Andean Blueberry Juice Powders for Potential Application as Functional Food Ingredients: Effect of Maltodextrin on Bioactive and Morphological Features. *Molecules*. 2020;25(23). Available from: https://doi.org/10.3390/molecules25235635.
13) Hariadi H, Wahyono T, Darniadi S, Maulana H, Nurhadi B, Amien S, et al. Effect of maltodextrin concentration and drying temperature on the physicochemical characteristics of Sacha inchi (*Plukenetia volubilis*) extract powder. *Italian journal of food sciences*. 2024;36(2):74–82. Available from: https://doi.org/10.15586/ijfs.v36i2.2458.
14) Islam MZ, Jahan MI, Monalisa K, Rana R, Hoque MM. Impact of maltodextrin, egg white protein addition and microwave-assisted foam mat drying on drying kinetics, microstructures, physicochemical and quality attributes of jackfruit juice powder. *Lebensmittel-Wissenschaft + Technologie-Food science & technology*. 2024;200:1–10. Available from: https://doi.org/10.1016/j.lwt.2024.116158.
15) Cacatian S, Guittap LJV. Production, proximate analysis and functional properties of Dragon Fruit peel powder. p. 1–14. Avail-able from: https://www.researchgate.net/publication/359209516_Production_Proximate_Analysis_and_Functional_Properties_of_Dragon_Fruit_Peel_ Powder/citations#fullTextFileContent.
16) Ezemba CC, Udoye IW, Chido-Esiegwu AM, Chidebe OP, Osuala O, Ezemba AS, et al. Evaluation of vinegar production properties of *Garcina kola* and A*rtocarpus heterophyllus. Journal of Applied Chemical Science International*. 2021;12(2):48–60. Available from: https://www.researchgate.net/publication/ 358262945_EVALUATION_OF_VINEGAR_PRODUCTION_PROPERTIES_OF_Garcina_kola_AND_Artocarpusheterophyllus.
17) Lee KC, Yoon YS, Li FZ, Eun JB. Effects of inlet air temperature and concentration of carrier agents on physicochemical properties, sensory evaluation of spray-dried mandarin (*Citrus unshiu)* beverage powder. *Applied Biological Chemistry*. 2017;60:33–40. Available from: https://link.springer.com/article/ 10.1007/s13765-016-0246-8.
18) Wongphan P, Harnkarnsujarit N. Characterization of starch, agar and maltodextrin blends for controlled dissolution of edible films. *International Journal of Biological Macromolecules*. 2020;156:80–93. Available from: https://doi.org/10.1016/j.ijbiomac.2020.04.056.
19) Arshimny NA, Syamsu K. Production and characteristic of natural coloring and flavoring preparations from pandan leaves (*Pandanus amaryllifolius*). *IOP Conference Series: Earth and Environmental Science*. 2020;472. Available from: https://iopscience.iop.org/article/10.1088/1755-1315/472/1/012014#: ~:text=Pandan%20leaves%20are%20extracted%20by,with%20an%2080%20mesh%20sieve.
20) Mellendorf C. 5% acidity vinegar is key to safe canning. 2023. Available from: https://extension.illinois.edu/news-releases/5-acidity-vinegar-key-safe-canning.
21) Frey M. Vinegar nutrition facts and health benefits. 2021. Available from: https://www.verywellfit.com/vinegar-nutrition-facts-and-health-benefits-5180624.
22) Bodor K, Szilágyi J, Salamon B, Szakács O, Bodor Z. Physical–chemical analysis of different types of flours available in the Romanian market. *Scientific Reports*. 2024;14. Available from: https://www.nature.com/articles/s41598-023-49535-x.
23) Karuppuchamy V, Heldman DR, Snyder AB. A review of food safety in low-moisture foods with current and potential dry-cleaning methods. *Journal of Food Science*. 2024;89(2):793–810. Available from: https://dx.doi.org/10.1111/1750-3841.16920.
24) Clouard C, Lannuzel C, Bourgot CL, Gerrits WJ. Lactose and digestible maltodextrin in milk replacers differently affect energy metabolism and substrate oxidation: A calorimetric study in piglets. *The Journal of Nutrition*. 2020;150(12):3114–3122. Available from: https://doi.org/10.1093/jn/nxaa296.