



Bibliography

- Acosta-Coello, C., Parodi-Redhead, A., & Medina-Pizzali, M. L. (2021). Design and validation of a nutritional recipe for a snack made of green banana peel flour (*Musa paradisiaca*). *Brazilian Journal of Food Technology/Brazilian Journal of Food Technology*, *24*. <https://doi.org/10.1590/1981-6723.34919>
- Adeola, A. A., & Ohizua, E. R. (2018). Physical, chemical, and sensory properties of biscuits prepared from flour blends of unripe cooking banana, pigeon pea, and sweet potato. *Food Science & Nutrition*, *6*(3), 532–540. <https://doi.org/10.1002/fsn3.590>
- Afzal, M. F., Khalid, W., Akram, S., Khalid, M. A., Zubair, M., Kauser, S., Mohamedahmed, K. A., Aziz, A., & Siddiqui, S. A. (2022). Bioactive profile and functional food applications of banana in food sectors and health: a review. *International Journal of Food Properties*, *25*(1), 2286–2300. <https://doi.org/10.1080/10942912.2022.2130940>
- Ahmed, H., Satheesh, N., & Dibaba, K. (2018). Functional, physical and sensory properties of cookies prepared from okara, red teff and wheat flours. *Croatian Journal of Food Science and Technology*, *10*(1), 23–32. <https://doi.org/10.17508/cjfst.2018.10.1.05>
- Ahmed, Z. F. R., Taha, E., Abdelkareem, N. a. A., & Mohamed, W. M. (2020). Postharvest properties of unripe bananas and the potential of producing economic nutritious products. *International Journal of Fruit Science*, *20*(sup2), S995–S1014. <https://doi.org/10.1080/15538362.2020.1774469>
- Ajala, A., Kaur, L., Lee, S. J., & Singh, J. (2022). Influence of seed microstructure on the hydration kinetics and oral-gastro-small intestinal starch digestion in vitro of New Zealand pea varieties. *Food Hydrocolloids*, *129*, 107631. <https://doi.org/10.1016/j.foodhyd.2022.107631>
- Ajjolokewu, K. A., Ayoola, A. S., Agbabiaka, T. O., Zakariyah, F. R., Ahmed, N. R., Oyedele, O. J., & Sani, A. (2021). A review of the ethnomedicinal, antimicrobial, and phytochemical properties of *Musa paradisiaca* (plantain). *Bulletin of the National Research Centre/Bulletin of the National Research Center*, *45*(1). <https://doi.org/10.1186/s42269-021-00549-3>

- Akintunde, T. Y., Musa, T. H., Musa, H. H., Musa, I. H., Chen, S., Ibrahim, E., Tassang, A. E., & Helmy, M. S. E. D. M. (2021). Bibliometric analysis of global scientific literature on effects of COVID-19 pandemic on mental health. *Asian Journal of Psychiatry*, *63*, 102753. <https://doi.org/10.1016/j.ajp.2021.102753>
- Alam, M., Biswas, M., Hasan, M. M., Hossain, M. F., Zahid, M. A., Al-Reza, M. S., & Islam, T. (2023). Quality attributes of the developed banana flour: Effects of drying methods. *Heliyon*, *9*(7), e18312. <https://doi.org/10.1016/j.heliyon.2023.e18312>
- Alkarkhi, A. F., Ramli, S. B., Yong, Y. S., & Easa, A. M. (2011). Comparing physicochemical properties of banana pulp and peel flours prepared from green and ripe fruits. *Food Chemistry*, *129*(2), 312–318. <https://doi.org/10.1016/j.foodchem.2011.04.060>
- Almanza-Benitez, S., Osorio-Díaz, P., Méndez-Montealvo, G., Islas-Hernández, J., & Bello-Perez, L. (2015). Addition of acid-treated unripe plantain flour modified the starch digestibility, indigestible carbohydrate content and antioxidant capacity of semolina spaghetti. *LWT*, *62*(2), 1127–1133. <https://doi.org/10.1016/j.lwt.2015.02.031>
- Al-Mqbali, L. R. A., & Hossain, M. A. (2019). Cytotoxic and antimicrobial potential of different varieties of ripe banana used traditionally to treat ulcers. *Toxicology Reports*, *6*, 1086–1090. <https://doi.org/10.1016/j.toxrep.2019.10.003>
- Allothman, M., Bhat, R., & Karim, A. (2009). Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. *Food Chemistry*, *115*(3), 785–788. <https://doi.org/10.1016/j.foodchem.2008.12.005>
- Alp, D., & Bulantekin, Ö. (2021). The microbiological quality of various foods dried by applying different drying methods: a review. *European Food Research and Technology*, *247*(6), 1333–1343. <https://doi.org/10.1007/s00217-021-03731-z>
- Alvarado-Jasso, G. M., Camacho-Díaz, B. H., Arenas-Ocampo, M. L., Jiménez-Ferrer, E., Mora-Escobedo, R., & Osorio-Díaz, P. (2020). Prebiotic effects of a mixture of agavins and green banana flour in a mouse model of obesity. *Journal of Functional Foods*, *64*, 103685. <https://doi.org/10.1016/j.jff.2019.103685>
- Amarasinghe, N. K., Wickramasinghe, I., Wijesekara, I., Thilakarathna, G., & Deyalage, S. T. (2021). Functional, Physicochemical, and Antioxidant Properties of Flour and

- Cookies from Two Different Banana Varieties (Musa acuminata cv. Pisang awak and Musa acuminata cv. Red dacca). *International Journal of Food Science*, 2021, 1–9. <https://doi.org/10.1155/2021/6681687>
- American Association of Cereal Chemists (AACC). (2000). *Approved methods of the Association of Cereal Chemist (10th ed.)*. St.Paul, MN: American Association of Cereal Chemists, University of Michigan. (n.d.).
- Anajekwu, E. O., Maziya-Dixon, B., Akinoso, R., Awoyale, W., & Alamu, E. O. (2020). Physicochemical Properties and Total Carotenoid Content of High-Quality Unripe Plantain Flour from Varieties of Hybrid Plantain Cultivars. *Journal of Chemistry*, 2020, 1–7. <https://doi.org/10.1155/2020/5960346>
- Anjana, R. M., Unnikrishnan, R., Deepa, M., Pradeepa, R., Tandon, N., Das, A. K., Joshi, S., Bajaj, S., Jabbar, P. K., Das, H. K., Kumar, A. M. V., Dhandhanian, V. K., Bhansali, A., Rao, P. V., Desai, A., Kalra, S., Gupta, A., Ramakrishnan, L., Madhu, S. V., . . . Ghosh, S. (2023). Metabolic non-communicable disease health report of India: the ICMR-INDIAB national cross-sectional study (ICMR-INDIAB-17). *The Lancet Diabetes & Endocrinology*, 11(7), 474–489. [https://doi.org/10.1016/s2213-8587\(23\)00119-5](https://doi.org/10.1016/s2213-8587(23)00119-5)
- Anyasi, T. A., Jideani, A. I., & Mchau, G. R. (2016). Effects of organic acid pretreatment on microstructure, functional and thermal properties of unripe banana flour. *Journal of Food Measurement & Characterization*, 11(1), 99–110. <https://doi.org/10.1007/s11694-016-9376-2>
- Anyasi, T. A., Jideani, A. I., & Mchau, G. R. (2018). Phenolics and essential mineral profile of organic acid pretreated unripe banana flour. *Food Research International*, 104, 100–109. <https://doi.org/10.1016/j.foodres.2017.09.063>
- AOAC International. (2005). *Official methods of analysis (18th ed.)*. Association of Official Analytical Chemists, Washington, DC. (n.d.).
- AOAC International. (2011). *Official methods of analysis (Method 2011.14)*. AOAC International. (n.d.).
- AOAC, 2002 AOAC Official Method of Analysis (sixteenth ed.), Association of Official Analytical, Washington DC, USA (2002). (n.d.).

- Aquino, C. F., Salomão, L. C. C., Cecon, P. R., De Siqueira, D. L., & Ribeiro, S. M. R. (2017). Physical, chemical and morphological characteristics of banana cultivars depending on maturation stages. *Revista Caatinga*, 30(1), 87–96. <https://doi.org/10.1590/1983-21252017v30n110rc>
- Arias, A., Feijoo, G., & Moreira, M. T. (2022). Exploring the potential of antioxidants from fruits and vegetables and strategies for their recovery. *Innovative Food Science & Emerging Technologies*, 77, 102974. <https://doi.org/10.1016/j.ifset.2022.102974>
- Ares, G., Giménez, A., & Deliza, R. (2009). Influence of three non-sensory factors on consumer choice of functional yogurts over regular ones. *Food Quality and Preference*, 21(4), 361–367. <https://doi.org/10.1016/j.foodqual.2009.09.002>
- Arinzechukwu, C. S., & Nkama, I. (2019). Production and Quality Evaluation of Fruit Bars from Banana (*Musa sapientum*) and Cashew (*Anacardium occidentale*) Apple Fruit Blends. *Asian Food Science Journal*, 1–16.
- Arp, C. G., Correa, M. J., & Ferrero, C. (2021). Resistant starches: A smart alternative for the development of functional bread and other starch-based foods. *Food Hydrocolloids*, 121, 106949. <https://doi.org/10.1016/j.foodhyd.2021.106949>
- Ashaolu, T. J. (2020). Immune boosting functional foods and their mechanisms: A critical evaluation of probiotics and prebiotics. *Biomedicine & Pharmacotherapy*, 130, 110625. <https://doi.org/10.1016/j.biopha.2020.110625>
- Asif-Ul-Alam, S. M., Islam, M. Z., Hoque, M. M., & Monalisa, K. (2014). Effects of Drying on the Physicochemical and Functional Properties of Green Banana (<i>Musa sapientum</i>) Flour and Development of Baked Product. *American Journal of Food Science and Technology*, 2(4), 128–133. <https://doi.org/10.12691/ajfst-2-4-4>
- Augustin, L., Kendall, C., Jenkins, D., Willett, W., et al., (2015). Glycemic index, glycemic load and glycemic response: An International Scientific Consensus Summit from the International Carbohydrate Quality Consortium (ICQC). *Nutrition Metabolism and Cardiovascular Diseases*, 25(9), 795–815.
- Aurore, G., Parfait, B., & Fährasmane, L. (2009). Bananas, raw materials for making processed food products. *Trends in Food Science & Technology*, 20(2), 78–91. <https://doi.org/10.1016/j.tifs.2008.10.003>

- Awuchi, C. G., Igwe, V. S., & Echeta, C. K. (2019). The functional properties of foods and flours. *International Journal of Advanced Academic Research*, 5(11), 139–141. <https://www.ijaar.org/articles/Volume5-Number11/Sciences-Technology-Engineering/ijaar-ste-v5n11-nov19-p16.pdf>
- Ayo-Omogie, H. N. (2023). Unripe banana and defatted sesame seed flours improve nutritional profile, dietary fibre and functional properties of gluten-free sorghum cookies. *Food Production Processing and Nutrition*, 5(1). <https://doi.org/10.1186/s43014-023-00147-y>
- Badjona, A., Bradshaw, R., Millman, C., Howarth, M., & Dubey, B. (2023). FABA Beans protein as an unconventional protein source for the food industry: processing influence on nutritional, Techno-Functionality, and bioactivity. *Food Reviews International*, 1–25. <https://doi.org/10.1080/87559129.2023.2245036>
- Baek, G. H., Kim, Y., Lee, Y., Jung, S., Seo, H. W., & Kim, J. (2023). Prebiotic potential of green banana flour: impact on gut microbiota modulation and microbial metabolic activity in a murine model. *Frontiers in Nutrition*, 10. <https://doi.org/10.3389/fnut.2023.1249358>
- Baixauli, R., Sanz, T., Salvador, A., & Fiszman, S. (2007). Muffins with resistant starch: Baking performance in relation to the rheological properties of the batter. *Journal of Cereal Science*, 47(3), 502–509. <https://doi.org/10.1016/j.jcs.2007.06.015>
- Baker, M. T., Lu, P., Parrella, J. A., & Leggette, H. R. (2022). Consumer Acceptance toward Functional Foods: A Scoping Review. *International Journal of Environmental Research and Public Health*, 19(3), 1217. <https://doi.org/10.3390/ijerph19031217>
- Bala, A., Gul, K., & Riar, C. S. (2015). Functional and sensory properties of cookies prepared from wheat flour supplemented with cassava and water chestnut flours. *Cogent Food & Agriculture*, 1(1), 1019815. <https://doi.org/10.1080/23311932.2015.1019815>
- Balmurugan, M., Saravanakumar, R., Kanchana, S., Vellaikumar, S., Mini, M., & Haripriya, S. (2022). Development of noodles using unripe banana flour and evaluation of its cooking characteristics and nutritional profile. *www.thepharmajournal.com*. <https://www.thepharmajournal.com/special-issue?year=2022&vol=11&issue=5S&ArticleId=12669>

- Balouiri, M., Sadiki, M., & Ibsouda, S. K. (2016). Methods for in vitro evaluating antimicrobial activity: A review. *Journal of Pharmaceutical Analysis*, 6(2), 71–79. <https://doi.org/10.1016/j.jpha.2015.11.005>
- Bamigbade, G. B., Subhash, A. J., Kamal-Eldin, A., Nyström, L., & Ayyash, M. (2022). An updated review on Prebiotics: Insights on potentials of food seeds waste as source of potential prebiotics. *Molecules*, 27(18), 5947. <https://doi.org/10.3390/molecules27185947>
- Baxter, N. T., Schmidt, A. W., Venkataraman, A., Kim, K. S., Waldron, C., & Schmidt, T. M. (2019). Dynamics of Human Gut Microbiota and Short-Chain Fatty Acids in Response to Dietary Interventions with Three Fermentable Fibers. *MBio*, 10(1). <https://doi.org/10.1128/mbio.02566-18>
- Belorio, M., & Gómez, M. (2020). Gluten-free muffins versus gluten containing muffins: Ingredients and nutritional differences. *Trends in Food Science & Technology*, 102, 249–253. <https://doi.org/10.1016/j.tifs.2020.03.015>
- Benzie, I. F., & Strain, J. (1996). The ferric reducing Ability of plasma (FRAP) as a measure of “Antioxidant power”: the FRAP assay. *Analytical Biochemistry*, 239(1), 70–76. <https://doi.org/10.1006/abio.1996.0292>
- Berger, K., Burleigh, S., Lindahl, M., Bhattacharya, A., Patil, P., Ståhlbrand, H., Karlsson, E. N., Hållenius, F., Nyman, M., & Adlercreutz, P. (2021). Xylooligosaccharides Increase Bifidobacteria and Lachnospiraceae in Mice on a High-Fat Diet, with a Concomitant Increase in Short-Chain Fatty Acids, Especially Butyric Acid. *Journal of Agricultural and Food Chemistry*, 69(12), 3617–3625. <https://doi.org/10.1021/acs.jafc.0c06279>
- Bi, Y., Zhang, Y., Jiang, H., Hong, Y., Gu, Z., Cheng, L., Li, Z., & Li, C. (2017). Molecular structure and digestibility of banana flour and starch. *Food Hydrocolloids*, 72, 219–227. <https://doi.org/10.1016/j.foodhyd.2017.06.003>
- Biernacka, B., Dziki, D., Różyło, R., & Gawlik-Dziki, U. (2020). Banana powder as an additive to common wheat pasta. *Foods*, 9(1), 53. <https://doi.org/10.3390/foods9010053>

- Bindels, L. B., Delzenne, N. M., Cani, P. D., & Walter, J. (2015). Towards a more comprehensive concept for prebiotics. *Nature Reviews Gastroenterology & Hepatology*, *12*(5), 303–310. <https://doi.org/10.1038/nrgastro.2015.47>
- Birt, D. F., Boylston, T., Hendrich, S., Jane, J., Hollis, J., Li, L., McClelland, J., Moore, S., Phillips, G. J., Rowling, M., Schalinske, K., Scott, M. P., & Whitley, E. M. (2013). Resistant Starch: Promise for improving human health. *Advances in Nutrition*, *4*(6), 587–601. <https://doi.org/10.3945/an.113.004325>
- Bodinham, C. L., Frost, G. S., & Robertson, M. D. (2009). Acute ingestion of resistant starch reduces food intake in healthy adults. *British Journal of Nutrition*, *103*(6), 917–922. <https://doi.org/10.1017/s0007114509992534>
- Bojarczuk, A., Skąpska, S., Khaneghah, A. M., & Marszałek, K. (2022). Health benefits of resistant starch: A review of the literature. *Journal of Functional Foods*, *93*, 105094. <https://doi.org/10.1016/j.jff.2022.105094>
- Borges, C. V., Amorim, E. P., Leonel, M., Gomez, H. a. G., Santos, T. P. R. D., Da Silva Ledo, C. A., Belin, M. a. F., De Almeida, S. L., Minatel, I. O., & Lima, G. P. P. (2019). Post-harvest physicochemical profile and bioactive compounds of 19 bananas and plantains genotypes. *Bragantia*, *78*(2), 284–296. <https://doi.org/10.1590/1678-4499.20180252>
- Brand-Miller, J., Hayne, S., Petocz, P., & Colagiuri, S. (2003). Low-Glycemic index diets in the management of diabetes. *Diabetes Care*, *26*(8), 2261–2267. <https://doi.org/10.2337/diacare.26.8.2261>
- Bubonja-Šonje, M., Knežević, S., & Abram, M. (2020). Challenges to antimicrobial susceptibility testing of plant-derived polyphenolic compounds. *Archives of Industrial Hygiene and Toxicology*, *71*(4), 300–311. <https://doi.org/10.2478/aiht-2020-71-3396>
- Buckman, E. S., Oduro, I., Plahar, W. A., & Tortoe, C. (2017). Determination of the chemical and functional properties of yam bean (*Pachyrhizus erosus* (L.) Urban) flour for food systems. *Food Science & Nutrition*, *6*(2), 457–463. <https://doi.org/10.1002/fsn3.574>
- Cahyana, Y., & Restiani, R. (2017). Wheat Flour Substitution with Retrograded Banana Flour to Produce Cookies Possessing Good Physical Characteristics and Low Glycemic Index. *KnE Life Sciences*, *2*(6), 556. <https://doi.org/10.18502/cls.v2i6.1075>

- Çakiroğlu, F. P., & Uçar, A. (2018). Consumer attitudes towards purchasing functional products. *Progress in Nutrition*, 20(2), 257–262. <https://doi.org/10.23751/pn.v20i2.5859>
- Campuzano, A., Rosell, C. M., & Cornejo, F. (2018). Physicochemical and nutritional characteristics of banana flour during ripening. *Food Chemistry*, 256, 11–17. <https://doi.org/10.1016/j.foodchem.2018.02.113>
- Canali, G., Balestra, F., Glicerina, V., Pasini, F., Caboni, M. F., & Romani, S. (2020). Influence of different baking powders on physico-chemical, sensory and volatile compounds in biscuits and their impact on textural modifications during soaking. *Journal of Food Science and Technology*, 57(10), 3864–3873. <https://doi.org/10.1007/s13197-020-04418-1>
- Cândido, H. T., Marzullo, Y. O. T., & Leonel, M. (2023). Green Banana Flour Technology: from Raw Material to Sensory Acceptance of Products Made with Green Banana Flour in the Brazilian Scenario. *Brazilian Archives of Biology and Technology*, 66. <https://doi.org/10.1590/1678-4324-2023210543>
- Cani, P. D. (2019). Targeting gut microbiota with a complex mix of dietary fibers improves metabolic diseases. *Kidney International*, 95(1), 14–16. <https://doi.org/10.1016/j.kint.2018.11.012>
- Carciochi, R. A., Manrique, G. D., & Dimitrov, K. (2014). Changes in phenolic composition and antioxidant activity during germination of quinoa seeds (*Chenopodium quinoa* Willd.). *International Food Research Journal*, 21((2)), 767-773.
- Cardoso, B. B., Amorim, C., Silvério, S. C., & Rodrigues, L. R. (2020). Novel and emerging prebiotics: Advances and opportunities. *Advances in Food and Nutrition Research*, 41–95. <https://doi.org/10.1016/bs.afnr.2020.08.001>
- Cassettari, V. M. G., Machado, N. C., De Arruda Lourenção, P. L. T., Carvalho, M. A., & Ortolan, E. V. P. (2018). Combinations of laxatives and green banana biomass on the treatment of functional constipation in children and adolescents: a randomized study. *Jornal De Pediatria*, 95(1), 27–33. <https://doi.org/10.1016/j.jpmed.2017.10.011>
- CEN. (2009c). *Foodstuffs – Determination of niacin by HPLC. EN 15652:2009. Brussels, Belgium: European Committee for Standardisation.* <https://www.cen.eu/>. (n.d.).

- Cena, H., & Calder, P. C. (2020). Defining a Healthy Diet: Evidence for the role of contemporary dietary patterns in Health and disease. *Nutrients*, *12*(2), 334. <https://doi.org/10.3390/nu12020334>
- Çetin-Babaoğlu, H., Coşkun, A., Taşçı, S., & Arslan-Tontul, S. (2024). Fermented unripe banana flour utilization as a functional ingredient in biscuits. *Plant Foods for Human Nutrition*. <https://doi.org/10.1007/s11130-024-01224-4>
- Chandra, S., & Samsher. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research*, *8*(38), 4849–4852. <https://doi.org/10.5897/ajar2013.6905>
- Chandra, S., Singh, S., & Kumari, D. (2014). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science and Technology*. <https://doi.org/10.1007/s13197-014-1427-2>
- Chang, C. R., Francois, M. E., & Little, J. P. (2019). Restricting carbohydrates at breakfast is sufficient to reduce 24-hour exposure to postprandial hyperglycemia and improve glycemic variability. *American Journal of Clinical Nutrition*, *109*(5), 1302–1309. <https://doi.org/10.1093/ajcn/nqy261>
- Chang, L., Yang, M., Zhao, N., Xie, F., Zheng, P., Simbo, J., Yu, X., & Du, S. (2022). Structural, physicochemical, antioxidant and in vitro digestibility properties of banana flours from different banana varieties (*Musa* spp.). *Food Bioscience*, *47*, 101624. <https://doi.org/10.1016/j.fbio.2022.101624>
- Cheng, Y., Huang, P., Chan, Y., Chiang, P., Lu, W., Hsieh, C., Liang, Z., Yan, B., Wang, C. R., & Li, P. (2024). Investigate the composition and physicochemical properties attributes of banana starch and flour during ripening. *Carbohydrate Polymer Technologies and Applications*, *7*, 100446. <https://doi.org/10.1016/j.carpta.2024.100446>
- Christi, W. A., Suwondo, A., & Setyaningsih, Y. (2019). Reduction of Fatigue Levels of Workers in the Construction Worker by Consuming Banana Chips with the Vacuum Frying Method. *E3S Web of Conferences*, *125*, 05004. <https://doi.org/10.1051/e3sconf/201912505004>

- Clodoveo, M. L., Muraglia, M., Fino, V., Curci, F., & Fracchiolla, G. (2021). Overview on innovative packaging methods aimed to increase the Shelf-Life of Cook-Chill foods. *Foods*, *10*(9), 2086. <https://doi.org/10.3390/foods10092086>
- Codex Alimentarius Commission. (1997). Nutrition and Health Claims (CAC/GL 23-1997). In *Nutrition and Health Claims (CAC/GL 23-1997)*. <https://www.fao.org/ag/humannutrition/32443-04352e8311b857c57caf5ffc4c5c4a4cd.pdf>
- Corallo, A., Latino, M. E., Menegoli, M., & Spennato, A. (2019). A survey to discover current food choice behaviors. *Sustainability*, *11*(18), 5041. <https://doi.org/10.3390/su11185041>
- Cordenunsi-Lysenko, B. R., Nascimento, J. R. O., Castro-Alves, V. C., Purgatto, E., Fabi, J. P., & Peroni-Okyta, F. H. G. (2019). The starch is (Not) just another brick in the wall: the primary metabolism of sugars during banana ripening. *Frontiers in Plant Science*, *10*. <https://doi.org/10.3389/fpls.2019.00391>
- Cornejo, F. (2015). Physicochemical properties of long rice grain varieties in relation to gluten free bread quality. *Lebensmittel-Wissenschaft + Technologie/Food Science & Technology*, *62*(2), 1203–1210. <https://doi.org/10.1016/j.lwt.2015.01.050>
- Cornejo, F., & Rosell, C. M. (2015). Physicochemical properties of long rice grain varieties in relation to gluten free bread quality. *LWT*, *62*(2), 1203–1210. <https://doi.org/10.1016/j.lwt.2015.01.050>
- Cornejo-Ramírez, Y. I., Martínez-Cruz, O., Del Toro-Sánchez, C. L., Wong-Corral, F. J., Borboa-Flores, J., & Cinco-Moroyoqui, F. J. (2018). The structural characteristics of starches and their functional properties. *CyTA - Journal of Food*, *16*(1), 1003–1017. <https://doi.org/10.1080/19476337.2018.1518343>
- Corso, M., Kalschne, D., & Benassi, M. (2018). Consumer's Attitude Regarding Soluble Coffee Enriched with Antioxidants. *Beverages*, *4*(4), 72. <https://doi.org/10.3390/beverages4040072>
- Da Mota, R.V., Lajolo, F.M., Cordenunsi, B.R. and Ciacco, C. (2000). Composition and Functional Properties of Banana Flour from Different Varieties. *Starch/Stärke*, *52*: 63-68.

- Da Silva Mendonça, J., De Cássia Avellaneda Guimarães, R., Zorretto-Pinheiro, V. A., Di Pietro Fernandes, C., Marcelino, G., Bogo, D., De Cássia Freitas, K., Hiane, P. A., De Pádua Melo, E. S., Vilela, M. L. B., & Nascimento, V. a. D. (2022). Natural Antioxidant Evaluation: A Review of Detection Methods. *Molecules/Molecules Online/Molecules Annual*, 27(11), 3563. <https://doi.org/10.3390/molecules27113563>
- Dadzie B K, & Orchard, J. E. (1997). Routine Post-Harvest Screening of Banana/Plantain Hybrids: Criteria and Methods. In *INIBAP Technical Guidelines 2* (pp. 75–85). International Plant Genetic Resources Institute, Montpellier.
- Dana, H., & Sonia, A. (2024). Substituting Sugar in Pastry and Bakery Products with Functional Ingredients. *Applied Sciences*, 14(18), 8563. <https://doi.org/10.3390/app14188563>
- Das, M., Rajan, N., Biswas, P., & Banerjee, R. (2022). A novel approach for resistant starch production from green banana flour using amylopullulanase. *LWT*, 153, 112391. <https://doi.org/10.1016/j.lwt.2021.112391>
- Davani-Davari, D., Negahdaripour, M., Karimzadeh, I., Seifan, M., Mohkam, M., Masoumi, S., Berenjian, A., & Ghasemi, Y. (2019). Prebiotics: definition, types, sources, mechanisms, and clinical applications. *Foods*, 8(3), 92. <https://doi.org/10.3390/foods8030092>
- Davies, N. T, & Reid, H. (1979). An evaluation of the phytate, zinc, copper, iron and manganese contents and Zn availability from, soyabasedtextured-vegetable-protein meat substitutes ormeat-extenders. *J.Nutr.* 41 (03): 579-589., 41(03), 579–589.
- De Andrade, L. S., Sardá, F. a. H., Pereira, N. B. F., Teixeira, R. R., Rodrigues, S. D., De Lima, J. D., Dalboni, M. A., Aoike, D. T., Nakao, L. S., & Cuppari, L. (2021). Effect of unripe banana flour on Gut-Derived uremic toxins in individuals undergoing peritoneal dialysis: a randomized, Double-Blind, Placebo-Controlled, crossover trial. *Nutrients*, 13(2), 646. <https://doi.org/10.3390/nu13020646>
- De Barros Mesquita, C., Leonel, M., Franco, C. M. L., Leonel, S., Garcia, E. L., & Santos, T. P. R. D. (2016). Characterization of banana starches obtained from cultivars grown in Brazil. *International Journal of Biological Macromolecules*, 89, 632–639. <https://doi.org/10.1016/j.ijbiomac.2016.05.040>

- De Brito, A. L. B., De Oliveira, A. F., Nogueira, A. R. A., Pessoa, A. G., & Pontes, L. F. B. L. (2017). Determination of inorganic constituents and physicochemical characterization of functional flour samples. *Microchemical Journal*, *132*, 112–118. <https://doi.org/10.1016/j.microc.2017.01.017>
- De Oliveira Lomeu, F. L. R., Vieira, C. R., Della Lucia, F., Veiga, S. M. O. M., Martino, H. S. D., & Silva, R. R. (2021). Cocoa and unripe banana flour beverages improve anthropometric and biochemical markers in overweight women: A randomised double-blind study. *International Journal for Vitamin and Nutrition Research*, *91*(3–4), 325–334. <https://doi.org/10.1024/0300-9831/a000637>
- De S Viana, E., De Souza, A. D. S., Reis, R. C., & De Oliveira, V. J. D. S. (2018). Aplicação de farinha de banana verde na substituição parcial da farinha de trigo em pão de forma. *Semina-ciencias Agrarias*, *39*(6), 2399. <https://doi.org/10.5433/1679-0359.2018v39n6p2399>
- Deka, D. C., & Neog, S. R. (2021). *Agricultural Benefits of Postharvest Banana Plants* (pp. 142–150). Bentham Science Publishers. <https://doi.org/10.2174/9789811801631121010014>
- Detchewa, P., Sriwichai, W., Moongngarm, A., & Prasajak, P. (2021). The effects of unripe banana flour on resistant starch content and quality characteristics of gluten-free rice cookies. *Journal of Sustainability Science and Management*, *16*(2), 67–78. <https://doi.org/10.46754/jssm.2021.02.008>
- Devisetti, R., Yadahally, S. N., & Bhattacharya, S. (2014). Nutrients and antinutrients in foxtail and proso millet milled fractions: Evaluation of their flour functionality. *LWT*, *59*(2), 889–895. <https://doi.org/10.1016/j.lwt.2014.07.003>
- Dhital, S., Katawal, S. B., & Shrestha, A. K. (2010). Formation of resistant starch during processing and storage of instant noodles. *International Journal of Food Properties*, *13*(3), 454–463. <https://doi.org/10.1080/10942910802627091>
- Di Cairano, M., Tchuenbou-Magaia, F. L., Condelli, N., Cela, N., Ojo, C. C., Radecka, I., Dunmore, S., & Galgano, F. (2022). Glycaemic Index of Gluten-Free Biscuits with Resistant Starch and Sucrose Replacers: An In Vivo and In Vitro Comparative Study. *Foods*, *11*(20), 3253. <https://doi.org/10.3390/foods11203253>

- Dibakoane, S. R., Du Plessis, B., Da Silva, L., Anyasi, T. A., Emmambux, M. N., Mlambo, V., & Wokadala, O. C. (2022). Nutraceutical Properties of unripe banana flour Resistant Starch: a review. *Starch-starke*. <https://doi.org/10.1002/star.202200041>
- Dodevska, M. S., Sobajic, S. S., Djordjevic, P. B., Dimitrijevic-Sreckovic, V. S., Spasojevic-Kalimanovska, V. V., & Djordjevic, B. I. (2015). Effects of total fibre or resistant starch-rich diets within lifestyle intervention in obese prediabetic adults. *European Journal of Nutrition*, *55*(1), 127–137. <https://doi.org/10.1007/s00394-015-0831-3>
- Dotto, J., Matem, A. O., & Ndakidemi, P. A. (2019). Nutrient composition and selected physicochemical properties of fifteen Mchare cooking bananas: A study conducted in northern Tanzania. *Scientific African*, *6*, e00150. <https://doi.org/10.1016/j.sciaf.2019.e00150>
- Du, Y., Wu, Y., Xiao, D., Guzman, G., Stewart, M. L., Gourineni, V., Burton-Freeman, B., & Edirisinghe, I. (2020). Food prototype containing resistant starch type 4 on postprandial glycemic response in healthy adults. *Food & Function*, *11*(3), 2231–2237. <https://doi.org/10.1039/c9fo02674f>
- Dufour, D., Gibert, O., Giraldo, A., Sanchez, T., Reynes, M., Pain, J. P., Gonzalez, A., Fernandez, A., & Diaz, A. (2009). *Characterisation of bananas and cooking bananas cultivated in Colombia: Morphological, physicochemical and functional differentiation between genetic groups, consumption patterns and preferences*. <https://agris.fao.org/search/en/providers/122653/records/64745b862437ad1e5b960f46>
- Edo, G. I., Makinde, M. G., Nwosu, L. C., Ozgor, E., & Akhayere, E. (2022). Physicochemical and Pharmacological Properties of Palm Oil: an Approach for Quality, Safety, and Nutrition Evaluation of Palm Oil. *Food Analytical Methods*, *15*(8), 2290–2305. <https://doi.org/10.1007/s12161-022-02293-4>
- EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). Scientific Opinion on the substantiation of health claims related to dietary fibre (ID 744, 745, 746, 748, 749, 753, 803, 810, 855, 1415, 1416, 4308, 4330) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. (2010). *EFSA Journal*, *8*(10), 1735. <https://doi.org/10.2903/j.efsa.2010.1735>
- Essa, M. M., Bishir, M., Bhat, A., Chidambaram, S. B., Al-Balushi, B., Hamdan, H., Govindarajan, N., Freidland, R. P., & Qoronfleh, M. W. (2021). Functional foods and

- their impact on health. *Journal of Food Science and Technology*, 60(3), 820–834. <https://doi.org/10.1007/s13197-021-05193-3>
- European Union Regulations No 1924/2006. (2006). *Dietary Fibre | Knowledge for policy*. An Official Website of the European Union. https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/dietary-fibre_en
- Fabbri, A. D., Schacht, R. W., & Crosby, G. A. (2016). Evaluation of resistant starch content of cooked black beans, pinto beans, and chickpeas. *NFS Journal*, 3, 8–12. <https://doi.org/10.1016/j.nfs.2016.02.002>
- Falcomer, A. L., Riquette, R. F. R., De Lima, B. R., Ginani, V. C., & Zandonadi, R. P. (2019). Health Benefits of Green banana Consumption: A Systematic review. *Nutrients*, 11(6), 1222. <https://doi.org/10.3390/nu11061222>
- FAO : *Bananas - Markets and Trade* (2023). <https://www.fao.org/markets-and-trade/commodities-overview/bananas-tropical-fruits/bananas/en>
- FAO KAP Manual-Guidelines for assessing nutrition-related Knowledge, Attitudes and Practices. (2014). In <https://www.fao.org/4/i3545e/i3545e00.htm>.
- FAO. (2003). *Food energy – methods of analysis and conversion factors* (FAO Food and Nutrition Paper 77). Rome: Food and Agriculture Organization of the United Nations.
- FAO *Banana facts and figures*. (2023.). www.fao.org. Retrieved January 10, 2023, from <https://www.fao.org/economic/est/est-commodities/oilcrops/bananas/bananafacts/en/#:~:text=There%20are%20more%20th an%201,are%20produced%20globally%20every%20year>.
- FDA *Daily value on the Nutrition and Supplement Facts labels*. (2024, March 5). U.S. Food And Drug Administration. <https://www.fda.gov/food/nutrition-facts-label/daily-value-nutrition-and-supplement-facts-labels>
- Fernando, I., Fei, J., Stanley, R., Enshaei, H., & Eyles, A. (2019). Quality deterioration of bananas in the post-harvest supply chain- an empirical study. *Modern Supply Chain Research and Applications*, 1(2), 135–154. <https://doi.org/10.1108/mscra-05-2019-0012>

- Ferreira, M. D. P., & Tarley, C. R. T. (2020). Assessment of in vitro bioaccessibility of macrominerals and trace elements in green banana flour. *Journal of Food Composition and Analysis*, 92, 103586. <https://doi.org/10.1016/j.jfca.2020.103586>
- Figueroa-González, I., Rodríguez-Serrano, G., Gómez-Ruiz, L., García-Garibay, M., & Cruz-Guerrero, A. (2019). Prebiotic effect of commercial saccharides on probiotic bacteria isolated from commercial products. *Food Science and Technology*, 39(3), 747–753. <https://doi.org/10.1590/fst.07318>
- Fonseca, L. M., Halal, S. L. M. E., Dias, Á. R. G., & Da Rosa Zavareze, E. (2021). Physical modification of starch by heat-moisture treatment and annealing and their applications: A review. *Carbohydrate Polymers*, 274, 118665. <https://doi.org/10.1016/j.carbpol.2021.118665>
- Fooks, L. J., & Gibson, G. R. (2002). In vitro investigations of the effect of probiotics and prebiotics on selected human intestinal pathogens. *FEMS Microbiology Ecology*, 39(1), 67–75. <https://doi.org/10.1111/j.1574-6941.2002.tb00907.x>
- FSSAI- Chapter 2 (peroxide Value). (n.d.). [https://www.fssai.gov.in/upload/uploadfiles/files/Chapter%20_2%20\(Fats%2C%20oils%20and%20fat%20emulsions\).pdf](https://www.fssai.gov.in/upload/uploadfiles/files/Chapter%20_2%20(Fats%2C%20oils%20and%20fat%20emulsions).pdf)
- FSSAI Manual on Method of Microbiological Testing 2016. (n.d.). https://fssai.gov.in/upload/uploadfiles/files/Microbiological_Testing_Foods_Draft_Manual_06_09_2016.pdf
- FSSAI Microbiological Standards - Appendix B. (n.d.). https://www.fssai.gov.in/upload/uploadfiles/files/20_%20Appendix%20B.pdf
- FSSAI_ Methods of analysis for Fortificants in Foods. (n.d.). In *Annexure*. https://www.fssai.gov.in/upload/advisories/2020/07/5f0d3a2a4132bOrder_Methods_Analysis_Fortificants_Food_13_07_2020.pdf
- Fu, J., Xiao, J., Tu, S., Sheng, Q., Yi, G., Wang, J., & Sheng, O. (2022). Plantain flour: A potential anti-obesity ingredient for intestinal flora regulation and improved hormone secretion. *Frontiers in Sustainable Food Systems*, 6. <https://doi.org/10.3389/fsufs.2022.1027762>

- Fuad, T., & Prabhasankar, P. (2010). Role of ingredients in pasta product Quality: A review on recent developments. *Critical Reviews in Food Science and Nutrition*, 50(8), 787–798. <https://doi.org/10.1080/10408390903001693>
- Fuentes -Zaragoza, E., Sánchez-Zapata, E., Sendra, E., Sayas, E., Navarro, C., Fernández-López, J., & Pérez-Alvarez, J. A. (2011). Resistant starch as prebiotic: A review. *Starch - Stärke*, 63(7), 406–415. <https://doi.org/10.1002/star.201000099>
- Galvez, F. C. F., & Resurreccion, A. (1992). Reliability of the Focus Group Technique in determining the Quality Characteristics of Mungbean [*Vigna Radiata* (L.) Wilczec] Noodles. *Journal of Sensory Studies*, 7(4), 315–326. <https://doi.org/10.1111/j.1745-459x.1992.tb00197.x>
- Ganapathiraju, M., & Fernandes, S. (2022). Consumer behavior and emotional satisfaction: Ready-To-Cook food products in India. *CARDIOMETRY*, 23, 728–740. <https://doi.org/10.18137/cardiometry.2022.23.728740>
- García-Solís, S. E., Bello-Pérez, L. A., Agama-Acevedo, E., & Flores-Silva, P. C. (2017). Plantain flour: A potential nutraceutical ingredient to increase fiber and reduce starch digestibility of gluten-free cookies. *Starch - Stärke*, 70(1–2). <https://doi.org/10.1002/star.201700107>
- Gibson, G. R., Hutkins, R., Sanders, M. E., Prescott, S. L., Reimer, R. A., Salminen, S. J., Scott, K., Stanton, C., Swanson, K. S., Cani, P. D., Verbeke, K., & Reid, G. (2017). Expert consensus document: The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. *Nature Reviews Gastroenterology & Hepatology*, 14(8), 491–502. <https://doi.org/10.1038/nrgastro.2017.75>
- Gilbert, De Louvois J, Donovan, T., & Little, C., Et Al. (2000). Guidelines for the microbiological quality of some ready-to-eat foods sampled at the point of sale. PHLS Advisory Committee for Food and Dairy Products. *Communicable Disease and Public Health.*, Sep;3(3), PMID: 11014026.
- Golovinskaia, O., & Wang, C. (2022). The hypoglycemic potential of phenolics from functional foods and their mechanisms. *Food Science and Human Wellness*, 12(4), 986–1007. <https://doi.org/10.1016/j.fshw.2022.10.020>

- Gomes, S., Vieira, B., Barbosa, C., & Pinheiro, R. (2020). Evaluation of mature banana peel flour on physical, chemical, and texture properties of a gluten-free Rissol. *Journal of Food Processing and Preservation*, *46*(8). <https://doi.org/10.1111/jfpp.14441>
- Goñi, I., García Alonso, A., & Saura Calixto, F. (1997). A starch hydrolysis procedure to estimate glycemic index. *Nutrition Research*, *17*(3), 427–437. [https://doi.org/10.1016/s0271-5317\(97\)00010-9](https://doi.org/10.1016/s0271-5317(97)00010-9)
- Goñi, I., García-Diz, L., Mañas, E., & Saura-Calixto, F. (1996). Analysis of resistant starch: a method for foods and food products. *Food Chemistry*, *56*(4), 445–449. [https://doi.org/10.1016/0308-8146\(95\)00222-7](https://doi.org/10.1016/0308-8146(95)00222-7)
- González-Díaz, C., Vilaplana-Aparicio, M. J., & Iglesias-García, M. (2020). How is functional food advertising understood? An approximation in university students. *Nutrients*, *12*(11), 3312. <https://doi.org/10.3390/nu12113312>
- Gourineni, V., Stewart, M., Skorge, R., & Wolever, T. M. S. (2019). Glycemic index of slowly digestible carbohydrate alone and in powdered Drink-Mix. *Nutrients*, *11*(6), 1228. <https://doi.org/10.3390/nu11061228>
- Granato, D., Barba, F. J., Kovačević, D. B., Lorenzo, J. M., Cruz, A. G., & Putnik, P. (2020). Functional foods: product development, technological trends, efficacy testing, and safety. *Annual Review of Food Science and Technology*, *11*(1), 93–118. <https://doi.org/10.1146/annurev-food-032519-051708>
- Gu, F., Li, C., Hamaker, B. R., Gilbert, R. G., & Zhang, X. (2020). Fecal microbiota responses to rice RS3 are specific to amylose molecular structure. *Carbohydrate Polymers*, *243*, 116475. <https://doi.org/10.1016/j.carbpol.2020.116475>
- Guan, Y., Yang, X., Pan, C., Kong, J., Wu, R., Liu, X., Wang, Y., Chen, M., Li, M., Wang, Q., He, G., Yang, G., Chang, J., Li, Y., & Wang, Y. (2023). Comprehensive Analyses of Breads Supplemented with Tannic Acids. *Foods*, *12*(20), 3756. <https://doi.org/10.3390/foods12203756>
- Gull, A., Prasad, K., & Kumar, P. (2016). Nutritional, antioxidant, microstructural and pasting properties of functional pasta. *Journal of the Saudi Society of Agricultural Sciences*, *17*(2), 147–153. <https://doi.org/10.1016/j.jssas.2016.03.002>

- Guo, J., Tan, L., & Kong, L. (2020). Impact of dietary intake of resistant starch on obesity and associated metabolic profiles in human: a systematic review of the literature. *Critical Reviews in Food Science and Nutrition*, 61(6), 889–905. <https://doi.org/10.1080/10408398.2020.1747391>
- Han Zhuorui, Xiao Junxiu, Ji Jianfei, Guo Yingxi, Wang Juan, & Sheng Ou. (2021). Anti-obesity Effects of Plantain Flour on Obese Rats Induced by High-fat Diet. *J. Science and Technology of Food Industry*, 42(6), 318–324. <https://doi.org/10.13386/j.issn1002-0306.2020060042>
- Haralampu, S. (2000). Resistant starch—a review of the physical properties and biological impact of RS3. *Carbohydrate Polymers*, 41(3), 285–292. [https://doi.org/10.1016/s0144-8617\(99\)00147-2](https://doi.org/10.1016/s0144-8617(99)00147-2)
- Hazarika, B. N., Sankaran, M., Menon, R., Sudha, R., Prakash, J., Kumar, P. S., Shiva, K. N., Singh, S. R., & Rabha, A. (2014). *Banana. In: Tropical and subtropical fruit crops: Crop improvement and varietal wealth (1st ed., p. 66). Jaya Publishing House. (S. N. Ghosh, Ed.). Jaya Publishing House.*
- Herrera-Agudelo, M. A., Miró, M., & Arruda, M. A. (2017). In vitro oral bioaccessibility and total content of Cu, Fe, Mn and Zn from transgenic (through cp4 EPSPS gene) and nontransgenic precursor/successor soybean seeds. *Food Chemistry*, 225, 125–131. <https://doi.org/10.1016/j.foodchem.2017.01.017>
- Ho, L., T, N. H., & AL, A. N. (2022). Nutritional compositions, physicochemical properties, and sensory attributes of green banana flour-based snack bar incorporated with konjac glucomannan. *Food Research*, 6(2), 128–138. [https://doi.org/10.26656/r.2017.6\(2\).275](https://doi.org/10.26656/r.2017.6(2).275)
- Horie, K., Hossain, S., Morita, S., Kim, Y., Yasuda, A., Watanabe, Y., Ohgitani, E., Mazda, O., & Kim, M. (2020). The potency of a novel fermented unripe banana powder as a functional immunostimulatory food ingredient. *Journal of Functional Foods*, 70, 103980. <https://doi.org/10.1016/j.jff.2020.103980>
- Hu, Y., Ting, Y., Hu, J., & Hsieh, S. (2017). Techniques and methods to study functional characteristics of emulsion systems. *Journal of Food and Drug Analysis*, 25(1), 16–26. <https://doi.org/10.1016/j.jfda.2016.10.021>

- Huang, L., Bai, L., & Gong, S. (2019). The effects of carrier, benefit, and perceived trust in information channel on functional food purchase intention among Chinese consumers. *Food Quality and Preference*, *81*, 103854. <https://doi.org/10.1016/j.foodqual.2019.103854>
- Huebner, J., Wehling, R., & Hutkins, R. (2007). Functional activity of commercial prebiotics. *International Dairy Journal*, *17*(7), 770–775. <https://doi.org/10.1016/j.idairyj.2006.10.006>
- Ibrahim, O. O. (2018). Functional oligosaccharide: chemicals structure, manufacturing, health benefits, applications and regulations. *Journal of Food Chemistry and Nanotechnology*, *04*(04). <https://doi.org/10.17756/jfcn.2018-060>
- IDF Diabetes Atlas 10th Edition*. (2021). https://diabetesatlas.org/idfawp/resource-files/2021/07/IDF_Atlas_10th_Edition_2021.pdf
- IMARC Group : India Food Processing Market Report by Sector (Dairy, Fruits and Vegetables, Meat and Poultry Processing, Fisheries, Packaged Foods, Beverages, and Others), and Region 2024-2032. (2023). In <https://www.imarcgroup.com/indian-food-processing-market> (SR112024A1056).
- Islam, M. F., Islam, S., Miah, M. a. S., Bhuiyan, M. N. I., Abedin, N., Mondol, M. M. H., Sultana, S., & Linkon, K. M. M. R. (2024). Quality assessment and sensory evaluation of green banana starch enriched instant noodles. *Applied Food Research*, *4*(1), 100431. <https://doi.org/10.1016/j.afres.2024.100431>
- Ivanišová, E., Drevková, B., Tokár, M., Terentjeva, M., Krajčovič, T., & Kačániová, M. (2019). Physicochemical and sensory evaluation of biscuits enriched with chicory fiber. *Food Science and Technology International*, *26*(1), 38–43. <https://doi.org/10.1177/1082013219864753>
- Iwe, M., Onyeukwu, U., & Agiriga, A. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. *Cogent Food & Agriculture*, *2*(1). <https://doi.org/10.1080/23311932.2016.1142409>
- Jacob, J., & Leelavathi, K. (2006). Effect of fat-type on cookie dough and cookie quality. *Journal of Food Engineering*, *79*(1), 299–305. <https://doi.org/10.1016/j.jfoodeng.2006.01.058>

- Jahan, N., Noor, R., & Munshi, S. K. (2019). Microbiological analysis and determination of antimicrobial traits of green banana (*Musa spp.*) and papaya (*Carica papaya*). *Stamford Journal of Microbiology*, 8(1), 41–45. <https://doi.org/10.3329/sjm.v8i1.42439>
- Jain, A., Madu, C. O., & Lü, Y. (2021). Phytochemicals in Chemoprevention: A Cost-Effective Complementary Approach. *Journal of Cancer*, 12(12), 3686–3700. <https://doi.org/10.7150/jca.57776>
- Jaiturong, P., Laosirisathian, N., Sirithunyalug, B., Eitssayeam, S., Sirilun, S., Chaiyana, W., & Sirithunyalug, J. (2020). Physicochemical and prebiotic properties of resistant starch from *Musa sapientum* Linn., ABB group, cv. Kluai Namwa Luang. *Heliyon*, 6(12), e05789. <https://doi.org/10.1016/j.heliyon.2020.e05789>
- Jalgaonkar, K., Jha, S. K., Nain, L., & Iquebal, M. A. (2017). *Quality Changes in Pearl Millet Based Pasta during Storage in Flexible Packaging*. <https://epubs.icar.org.in/index.php/JAE/article/view/78973>
- Jannoey, P., Duangdao Channei, Tantip Boonsong, Suchada Pimsen, & And Nitra Nueangjumnong. (2021). Phytochemical screening and Antioxidant activity of Unripe Banana flour. *NU. International Journal Of Science*, 18(2), 80–102. <https://www.sci.nu.ac.th/sciencejournal/index.php/sci/article/view/ID493/pdf>
- Jenkins, A. L., Jenkins, D. J., Wolever, T. M., Rogovik, A. L., Jovanovski, E., Božikov, V., Rahelić, D., & Vuksan, V. (2008). Comparable Postprandial Glucose Reductions with Viscous Fiber Blend Enriched Biscuits in Healthy Subjects and Patients with Diabetes Mellitus: Acute Randomized Controlled Clinical Trial. *Croatian Medical Journal*, 49(6), 772–782. <https://doi.org/10.3325/cmj.2008.49.722>
- Jenkins, D. J., Wesson, V., Wolever, T. M., Jenkins, A. L., Kalmusky, J., Guidici, S., Csimá, A., Josse, R. G., & Wong, G. S. (1988). Wholemeal versus wholegrain breads: proportion of whole or cracked grain and the glycaemic response. *BMJ*, 297(6654), 958–960. <https://doi.org/10.1136/bmj.297.6654.958>
- Jiang, H., Zhang, Y., Hong, Y., Yu, B., Gu, Z., Cheng, L., Li, Z., & Li, C. (2015). Digestibility and changes to structural characteristics of green banana starch during in vitro digestion. *Food Hydrocolloids*, 49, 192–199. <https://doi.org/10.1016/j.foodhyd.2015.03.023>

- Juarez-Garcia, E., Agama-Acevedo, E., Sáyago-Ayerdi, S., Rodríguez-Ambriz, S., & Bello-Pérez, L. (2006). Composition, digestibility and application in breadmaking of banana flour. *Plant Foods for Human Nutrition*, *61*(3), 131–137. <https://doi.org/10.1007/s11130-006-0020-x>
- Kahraman, K., Aktas-Akyildiz, E., Ozturk, S., & Koxsel, H. (2019). Effect of different resistant starch sources and wheat bran on dietary fibre content and in vitro glycaemic index values of cookies. *Journal of Cereal Science*, *90*, 102851. <https://doi.org/10.1016/j.jcs.2019.102851>
- Kamal, M. M., Ove, T. A., Saifullah, S. B., & Haque, M. R. (2022). Effects of citric acid and potassium metabisulphite Pre-Treatment on the physical and biochemical properties of dehydrated amritsagar banana powder. *Trends in Sciences*, *19*(5), 2893. <https://doi.org/10.48048/tis.2022.2893>
- Kamel, R., Afifi, S. M., Kassem, I. A., Elkasabgy, N. A., & Farag, M. A. (2020). Arabinoxylan and rhamnogalacturonan mucilage: Outgoing and potential trends of pharmaceutical, environmental, and medicinal merits. *International Journal of Biological Macromolecules*, *165*, 2550–2564. <https://doi.org/10.1016/j.ijbiomac.2020.10.175>
- Kan, J., Wu, F., Wang, F., Zheng, J., Cheng, J., Li, Y., Yang, Y., & Du, J. (2022). Phytonutrients: Sources, bioavailability, interaction with gut microbiota, and their impacts on human health. *Frontiers in Nutrition*, *9*. <https://doi.org/10.3389/fnut.2022.960309>
- Kancherla, N., Dhakshinamoothi, A., Chitra, K., & Komaram, R. B. (2019). Preliminary Analysis of Phytoconstituents and Evaluation of Anthelmintic Property of Cayratia auriculata (In Vitro). *MAEDICA – a Journal of Clinical Medicine*, *14*(4). <https://doi.org/10.26574/maedica.2019.14.4.350>
- Karelakis, C., Zevgitis, P., Γαλανόπουλος, K., & Mattas, K. (2019). Consumer trends and attitudes to functional foods. *Journal of International Food & Agribusiness Marketing*, *32*(3), 266–294. <https://doi.org/10.1080/08974438.2019.1599760>
- Kaur, A., Shevkani, K., Singh, N., Sharma, P., & Kaur, S. (2015). Effect of guar gum and xanthan gum on pasting and noodle-making properties of potato, corn and mung bean

- starches. *Journal of Food Science and Technology*, 52(12), 8113–8121. <https://doi.org/10.1007/s13197-015-1954-5>
- Kaur, P., Choudhary, M., & Sharma, S. (2023). Fatty acid profiling and oxidative stability of biscuits available in the market of the city of Ludhiana, India. *Scientific Reports*, 13(1). <https://doi.org/10.1038/s41598-023-44228-x>
- Kaur, P., Kaur, H., Aggarwal, R., Bains, K., Mahal, A. K., Gupta, O. P., Singla, L. D., & Singh, K. (2023a). Effect of cooking and storage temperature on resistant starch in commonly consumed Indian wheat products and its effect upon blood glucose level. *Frontiers in Nutrition*, 10. <https://doi.org/10.3389/fnut.2023.1284487>
- Keenan, M. J., Zhou, J., Hegsted, M., Pelkman, C., Durham, H., Coulon, D., & Martin, R. J. (2015). Role of resistant starch in improving gut health, adiposity, and insulin resistance. *Advances in Nutrition*, 6(2), 198–205. <https://doi.org/10.3945/an.114.007419>
- Khalid, A., Hameed, A., & Tahir, M. F. (2023). Wheat quality: A review on chemical composition, nutritional attributes, grain anatomy, types, classification, and function of seed storage proteins in bread making quality. *Frontiers in Nutrition*, 10. <https://doi.org/10.3389/fnut.2023.1053196>
- Khan, A., Ali, H., Rehman, U. U., Belduz, A. O., Bibi, A., Abdurahman, M. A., Shah, A. A., Badshah, M., Hasan, F., Kilic, A. O., Ullah, A., Jahan, S., Rehman, M. M. U., Mansoor, R., & Khan, S. (2022). Prebiotic potential of enzymatically prepared resistant starch in reshaping gut microbiota and their respond to body physiology. *PLoS ONE*, 17(5), e0267318. <https://doi.org/10.1371/journal.pone.0267318>
- Khawas, P., & Deka, S. C. (2016). Effect of modified resistant starch of culinary banana on physicochemical, functional, morphological, diffraction, and thermal properties. *International Journal of Food Properties*, 20(1), 133–150. <https://doi.org/10.1080/10942912.2016.1147459>
- Khoozani, A. A., Birch, J., & Bekhit, A. E. A. (2019). Production, application and health effects of banana pulp and peel flour in the food industry. *Journal of Food Science and Technology*, 56(2), 548–559. <https://doi.org/10.1007/s13197-018-03562-z>

- Khoozani, A. A., Kebede, B., Birch, J., & Bekhit, A. E. A. (2020). The Effect of Bread Fortification with Whole Green Banana Flour on Its Physicochemical, Nutritional and In Vitro Digestibility. *Foods*, 9(2), 152. <https://doi.org/10.3390/foods9020152>
- Khorasaniha, R., Olof, H., Voisin, A., Armstrong, K., Wine, E., Vasanthan, T., & Armstrong, H. (2023). Diversity of fibers in common foods: Key to advancing dietary research. *Food Hydrocolloids*, 139, 108495. <https://doi.org/10.1016/j.foodhyd.2023.108495>
- Khoza, M., Kayitesi, E., & Dlamini, B. C. (2021). Physicochemical characteristics, microstructure and health promoting properties of green banana flour. *Foods*, 10(12), 2894. <https://doi.org/10.3390/foods10122894>
- Kouamé, C. A., Kouassi, N. K., Abodo, J., Pereko, K. K. A., Casiraghi, M. C., N'Dri, D. Y., & Amani, G. N. (2017). Glycemic Responses, Glycemic Index, and Glycemic Load Values of Some Street Foods Prepared from Plantain (*Musa* spp., AAB Genome) in Côte d'Ivoire. *Foods*, 6(9), 83. <https://doi.org/10.3390/foods6090083>
- Kraithong, S., Wang, S., Junejo, S. A., Fu, X., Theppawong, A., Zhang, B., & Huang, Q. (2021). Type 1 resistant starch: Nutritional properties and industry applications. *Food Hydrocolloids*, 125, 107369. <https://doi.org/10.1016/j.foodhyd.2021.107369>
- Kritsi, E., Tsiaka, T., Sotiroudis, G., Mouka, E., Aouant, K., Ladika, G., Zoumpoulakis, P., Cavouras, D., & Sinanoglou, V. J. (2023). Potential Health Benefits of Banana Phenolic Content during Ripening by Implementing Analytical and In Silico Techniques. *Life*, 13(2), 332. <https://doi.org/10.3390/life13020332>
- Krutulyte, R., Grunert, K. G., Scholderer, J., Lähteenmäki, L., Hagemann, K. S., Elgaard, P., Nielsen, B., & Graverholt, J. P. (2010). Perceived fit of different combinations of carriers and functional ingredients and its effect on purchase intention. *Food Quality and Preference*, 22(1), 11–16. <https://doi.org/10.1016/j.foodqual.2010.06.001>
- Kukade, A.G., Pawar, V.S., Syed, H.M., & Dipak Sharma. (2017). Development and evaluation of organoleptic and microbial quality of guar gum incorporated composite flour cookies. *Journal of Pharmacognosy and Phytochemistry*, 6(5), 716–720. <https://www.phytojournal.com/archives/2017/vol6issue5/PartK/6-4-453-508.pdf>
- Kumar, A., Sahu, C., Panda, P. A., Biswal, M., Sah, R. P., Lal, M. K., Baig, M. J., Swain, P., Behera, L., Chattopadhyay, K., & Sharma, S. (2019). Phytic acid content may affect

- starch digestibility and glycemic index value of rice (*Oryza sativa* L.). *Journal of the Science of Food and Agriculture*, 100(4), 1598–1607. <https://doi.org/10.1002/jsfa.10168>
- Kumar, L. R. G., Kumar, H. S., Tejpal, C. S., Anas, K. K., Nayak, B. B., Sarika, K., Greeshma, S. S., Chatterjee, N. S., Mathew, S., & Ravishankar, C. N. (2021b). Exploring the physical and quality attributes of muffins incorporated with microencapsulated squalene as a functional food additive. *Journal of Food Science and Technology*, 58(12), 4674–4684. <https://doi.org/10.1007/s13197-020-04955-9>
- Kumar, P. S., Saravanan, A., Narayanan, S., Shiva, K., Ravi, I., Mayilvaganan, M., Pushpa, R., & Uma, S. (2021a). Exploring differences in the physicochemical, functional, structural, and pasting properties of banana starches from dessert, cooking, and plantain cultivars (*Musa* spp.). *International Journal of Biological Macromolecules*, 191, 1056–1067. <https://doi.org/10.1016/j.ijbiomac.2021.09.172>
- Kumar, P. S., Saravanan, A., Sheeba, N., & Uma, S. (2019). Structural, functional characterization and physicochemical properties of green banana flour from dessert and plantain bananas (*Musa* spp.). *Lebensmittel-Wissenschaft + Technologie/Food Science & Technology*, 116, 108524. <https://doi.org/10.1016/j.lwt.2019.108524>
- Kumari, P., Gaur, S. S., & Tiwari, R. K. (2023). Banana and its by-products: A comprehensive review on its nutritional composition and pharmacological benefits. *eFood*, 4(5). <https://doi.org/10.1002/efd2.110>
- Landström, E., Hursti, U. K., & Magnusson, M. (2009). “Functional foods compensate for an unhealthy lifestyle”. Some Swedish consumers’ impressions and perceived need of functional foods. *Appetite*, 53(1), 34–43. <https://doi.org/10.1016/j.appet.2009.04.219>
- Latif, A., Shehzad, A., Niazi, S., Zahid, A., Ashraf, W., Iqbal, M. W., Rehman, A., Riaz, T., Aadil, R. M., Khan, I. M., Özogul, F., Rocha, J. M., Esatbeyoglu, T., & Korma, S. A. (2023). Probiotics: mechanism of action, health benefits and their application in food industries. *Frontiers in Microbiology*, 14. <https://doi.org/10.3389/fmicb.2023.1216674>
- Lee, J. S., Yusoff, N., Ho, A. L., Siew, C. K., Akanda, J. H., & Tan, W. C. (2023). Quality improvement of Green Saba banana flour steamed cake. *Applied Sciences*, 13(4), 2421. <https://doi.org/10.3390/app13042421>

- Li, C., Gong, B., Hu, Y., Liu, X., Guan, X., & Zhang, B. (2020). Combined crystalline, lamellar and granular structural insights into in vitro digestion rate of native starches. *Food Hydrocolloids*, *105*, 105823. <https://doi.org/10.1016/j.foodhyd.2020.105823>
- Li, M., Chou, C., Hsu, S., & Lin, J. (2020). Physicochemical characteristics and resistant starch of different varieties of banana from Taiwan. *International Journal of Food Properties*, *23*(1), 1168–1175. <https://doi.org/10.1080/10942912.2020.1788077>
- Li, P., Li, M., Song, Y., Huang, X., Wu, T., Xu, Z. Z., & Lu, H. (2022). Green banana flour contributes to gut microbiota recovery and improves colonic barrier integrity in mice following antibiotic perturbation. *Frontiers in Nutrition*, *9*. <https://doi.org/10.3389/fnut.2022.832848>
- Li, P., Wang, C., Lu, W., Chan, Y., & Wang, C. R. (2022). Effect of resistant starch sources on the physical properties of dough and on the eating quality and glycemic index of salted noodles. *Foods*, *11*(6), 814. <https://doi.org/10.3390/foods11060814>
- Liang, M., Tu, S., Fu, J., Wang, J., & Sheng, O. (2024). Structural and Physicochemical Characterization of Resistant Starch from Sixteen Banana Cultivars across Three Genome Groups. *Foods*, *13*(20), 3277. <https://doi.org/10.3390/foods13203277>
- Lim, J. (2011). Hedonic scaling: A review of methods and theory. *Food Quality and Preference*. <https://doi.org/10.1016/j.foodqual.2011.05.008>
- Lima, C. T., Santos, T. M. D., De Andrade Neves, N., Lavado-Cruz, A., Paucar-Menacho, L. M., Clerici, M. T. P. S., Meza, S. L. R., & Schmiele, M. (2023). New Breakfast Cereal Developed with Sprouted Whole Ryegrass Flour: Evaluation of Technological and Nutritional Parameters. *Foods*, *12*(21), 3902. <https://doi.org/10.3390/foods12213902>
- Longvah T Ananthan, .R , Bhaskarachary, K., Venkaiah, K. (2017). *Indian Food Composition Table 2017*, National Institute of Nutrition. Hyderabad, India. National Institute of Nutrition, ICMR, Hyderabad, India.
- Mahoney, R. R. (1998). Galactosyl-oligosaccharide formation during lactose hydrolysis: A review. *Food Chemistry*, *63*(2), 147–154. [https://doi.org/10.1016/s0308-8146\(98\)00020-x](https://doi.org/10.1016/s0308-8146(98)00020-x)

- Mamat, H., Addrian, I., Adawiyah, Z. U. B., Mansoor, A., & Zainol, M. (2021). Evaluation of physicochemical and functional characteristics of flour from three cultivars of unripe banana (*Musa* sp.) cultivated in Sabah, Malaysia. *Food Research*, 5(4), 135–144. [https://doi.org/10.26656/fr.2017.5\(4\).642](https://doi.org/10.26656/fr.2017.5(4).642)
- Manonmani, S., Senthilkumar, S., & Manivannan, S. (2023). Influence of plant bioregulators on finger characters, yield and economics of banana cv. Monthan under the Cauvery delta region of Karaikal, Puducherry. *Journal of Applied and Natural Science*, 15(4), 1701–1705. <https://doi.org/10.31018/jans.v15i4.4934>
- Manzocco, L., Romano, G., Calligaris, S., & Nicoli, M. C. (2020). Modeling the effect of the oxidation status of the ingredient oil on stability and shelf life of Low-Moisture bakery products: The Case Study of Crackers. *Foods*, 9(6), 749. <https://doi.org/10.3390/foods9060749>
- Macías, Y.F., & Peter Glasauer, P. (2014). *Guidelines for assessing nutrition-related Knowledge, Attitudes and Practices*. <https://www.fao.org/4/i3545e/i3545e00.htm>. <https://www.fao.org/4/i3545e/i3545e.pdf>
- Markovina, J., Čačić, J., Kljusurić, J. G., & Kovačić, D. (2011). Young consumers' perception of functional foods in Croatia. *British Food Journal*, 113(1), 7–16. <https://doi.org/10.1108/00070701111097303>
- Marta, H., Cahyana, Y., Djali, M., & Pramafisi, G. (2022). The properties, modification, and application of banana starch. *Polymers*, 14(15), 3092. <https://doi.org/10.3390/polym14153092>
- Martens, B. M. J., Gerrits, W. J. J., Bruininx, E. M. a. M., & Schols, H. A. (2018). Amylopectin structure and crystallinity explains variation in digestion kinetics of starches across botanic sources in an in vitro pig model. *Journal of Animal Science and Biotechnology/Journal of Animal Science and Biotechnology*, 9(1). <https://doi.org/10.1186/s40104-018-0303-8>
- Maseko, K. H., Regnier, T., Meiring, B., Wokadala, O. C., & Anyasi, T. A. (2023). *Musa* species variation, production, and the application of its processed flour: A review. *Scientia Horticulturae*, 325, 112688. <https://doi.org/10.1016/j.scienta.2023.112688>

- Mathew, N. S., & Negi, P. S. (2016). Traditional uses, phytochemistry and pharmacology of wild banana (*Musa acuminata* Colla): A review. *Journal of Ethnopharmacology*, *196*, 124–140. <https://doi.org/10.1016/j.jep.2016.12.009>
- Mazhar, M., Zhu, Y., & Qin, L. (2023). The interplay of dietary fibers and intestinal microbiota affects type 2 diabetes by generating Short-Chain fatty acids. *Foods*, *12*(5), 1023. <https://doi.org/10.3390/foods12051023>
- Maziarz, M. P., Preisendanz, S., Juma, S., Imrhan, V., Prasad, C., & Vijayagopal, P. (2017). Resistant starch lowers postprandial glucose and leptin in overweight adults consuming a moderate-to-high-fat diet: a randomized-controlled trial. *Nutrition Journal*, *16*(1). <https://doi.org/10.1186/s12937-017-0235-8>
- Megur, A., Daliri, E. B., Baltriukienė, D., & Burokas, A. (2022). Prebiotics as a tool for the prevention and treatment of obesity and diabetes: Classification and ability to modulate the gut microbiota. *International Journal of Molecular Sciences*, *23*(11), 6097. <https://doi.org/10.3390/ijms23116097>
- Menezes, E. W., Dan, M. C. T., Cardenette, G. H. L., Goñi, I., Bello-Pérez, L. A., & Lajolo, F. M. (2010). In vitro colonic fermentation and glycemic response of different kinds of unripe banana flour. *Plant Foods for Human Nutrition*, *65*(4), 379–385. <https://doi.org/10.1007/s11130-010-0190-4>
- Mirosa, M., & Mangan-Walker, E. (2017). Young Chinese and functional foods for mobility health: perceptions of importance, trust, and willingness to purchase and pay a premium. *Journal of Food Products Marketing*, *24*(2), 216–234. <https://doi.org/10.1080/10454446.2017.1266555>
- MOFPI - *Sector Profile- READY TO EAT /READY TO COOK /READY TO DRINK*. (2023). Ministry of Food Processing Industries, Government of India. https://wfindia.s3.ap-south-1.amazonaws.com/website_images/pdf/1691752912_1095741203.pdf
- MOFPI : *Food Processing in India | Food Processing Industry in India* | Retrieved November 10, 2024, from <https://www.foodprocessingindia.gov.in/state/tamil-nadu>
- MOFPI Annual Report 2022-23. In https://www.mofpi.gov.in/sites/default/files/mofpi_annual_report_2023_eng_5-6-2023_new.pdf. MOFPI. Retrieved October 20,

- 2024, from https://www.mofpi.gov.in/sites/default/files/mofpi_annual_report_2023_eng_5-6-2023_new.pdf
- Mondal, A., Banerjee, S., Bose, S., Das, P. P., Sandberg, E. N., Atanasov, A. G., & Bishayee, A. (2021). Cancer Preventive and therapeutic Potential of banana and its bioactive constituents: A Systematic, comprehensive, and Mechanistic review. *Frontiers in Oncology, 11*. <https://doi.org/10.3389/fonc.2021.697143>
- Mondal, D. D., Chakraborty, U., Bera, M., Ghosh, S., & Kar, D. (2023). An overview of nutritional profiling in foods: Bioanalytical techniques and useful protocols. *Frontiers in Nutrition, 10*. <https://doi.org/10.3389/fnut.2023.1124409>
- Monjotin, N., Amiot, M. J., Fleurentin, J., Morel, J. M., & Raynal, S. (2022). Clinical evidence of the benefits of phytonutrients in human healthcare. *Nutrients, 14*(9), 1712. <https://doi.org/10.3390/nu14091712>
- Mora, M. R., Wang, Z., Goddard, J. M., & Dando, R. (2022). Consumers respond positively to the sensory, health, and sustainability benefits of the rare sugar allulose in yogurt formulations. *Foods, 11*(22), 3718. <https://doi.org/10.3390/foods11223718>
- Mordor Intelligence: Detailed research report on the ready-to-eat food market, featuring market trends, industry analysis, size, and growth report from 2024 to 2029. (2023). In <https://www.mordorintelligence.com/industry-reports/ready-to-eat-food-market>. Mordor Intelligence.
- Mostafa, H. S. (2021). Banana plant as a source of valuable antimicrobial compounds and its current applications in the food sector. *Journal of Food Science, 86*(9), 3778–3797. <https://doi.org/10.1111/1750-3841.15854>
- Munir, H., Alam, H., Nadeem, M. T., Almalki, R. S., Arshad, M. S., & Suleria, H. a. R. (2024). Green banana resistant starch: A promising potential as functional ingredient against certain maladies. *Food Science & Nutrition, 12*(6), 3787–3805. <https://doi.org/10.1002/fsn3.4063>
- Nandiyanto, A. B. D., Oktiani, R., & Ragadhita, R. (2019). How to read and interpret FTIR spectroscopy of organic material. *Indonesian Journal of Science and Technology, 4*(1), 97. <https://doi.org/10.17509/ijost.v4i1.15806>

- Naumov, K. (2023). The employment of standardized recipes, an essential prerequisite for consistent quality of the culinary product. *International Scientific Conference ERAZ. Knowledge Based Sustainable Development*. <https://doi.org/10.31410/eraz.2023.401>
- Netshiheni, R. K., Omolola, A. O., Anyasi, T. A., & Jideani, A. I. (2019). Banana bioactives: absorption, utilisation and health benefits. In *IntechOpen eBooks*. <https://doi.org/10.5772/intechopen.83369>
- Ni, C., Jia, Q., Ding, G., Wu, X., & Yang, M. (2022). Low-Glycemic Index Diets as an Intervention in Metabolic Diseases: A Systematic Review and Meta-Analysis. *Nutrients*, *14*(2), 307. <https://doi.org/10.3390/nu14020307>
- Nikolic, P., & Mudgil, P. (2023). The Cell Wall, Cell Membrane and Virulence Factors of *Staphylococcus aureus* and Their Role in Antibiotic Resistance. *Microorganisms*, *11*(2), 259. <https://doi.org/10.3390/microorganisms11020259>
- Njapndouké, B., Saah, M. B. D., Marius, F. K. E., Bouno, G. T., & Ngoufack, F. Z. (2021). Optimum biscuit from *Musa sapientum* L. and *Vigna unguiculata* L. composite flour: effect on pancreatic histology, biochemical and hematological parameters of diabetic rats. *Heliyon*, *7*(9), e07987. <https://doi.org/10.1016/j.heliyon.2021.e07987>
- Nogacka, A. M., Salazar, N., Arbolea, S., Ruas-Madiedo, P., Mancabelli, L., Suarez, A., Martinez-Faedo, C., Ventura, M., Tochio, T., Hirano, K., Endo, A., De Los Reyes-Gavilán, C. G., & Gueimonde, M. (2020). In vitro evaluation of different prebiotics on the modulation of gut microbiota composition and function in morbid obese and Normal-Weight subjects. *International Journal of Molecular Sciences*, *21*(3), 906. <https://doi.org/10.3390/ijms21030906>
- OECD Consensus Document on the Biology of Bananas and Plantains (Musa spp.) ENV/JM/MONO(2009)43*. (2009). Web Site (<http://www.oecd.org/biotrack>).
- Okafor, G., & Usman, G. (2013). Production and Evaluation of Breakfast Cereals from Blends of African Yam Bean (*Sphenostylis stenocarpa*), Maize (*Zea mays*) and Defatted Coconut (*Cocos nucifera*). *Journal of Food Processing and Preservation*, *38*(3), 1037–1043. <https://doi.org/10.1111/jfpp.12060>
- Olawoye, B., Fagbohun, O. F., Popoola-Akinola, O., Adetola, D. B., Gbadamosi, S. O., & Akanbi, C. T. (2023). That we may eat and be healthy: A case of slowly digestible cookies from cardaba banana starch. *Applied Food Research*, *3*(2), 100342. <https://doi.org/10.1016/j.afres.2023.100342>

- Onuoha, N., Okafor, A., & Okeke, L. (2019). Glycaemic indices of unripe plantain (*Musa paradisiaca*) and unripe red banana (*Musa* sp. AAA) flour meals. *Bio-Research*, *15*(1), 955. <https://doi.org/10.4314/br.v15i1.188318>
- Osorio-Díaz, P., Islas-Hernández, J. J., Agama-Acevedo, E., Rodríguez-Ambríz, S. L., Sánchez-Pardo, M. E., & Bello-Pérez, L. A. (2014). Chemical, starch digestibility and sensory characteristics of Durum Wheat/Unripe Whole Banana flour blends for spaghetti formulation. *Food and Nutrition Sciences*, *05*(03), 264–270. <https://doi.org/10.4236/fns.2014.53033>
- Ouyang, Q., Wang, X., Xiao, Y., Luo, F., Lin, Q., & Ding, Y. (2021). Structural changes of A-, B- and C-type starches of corn, potato and pea as influenced by sonication temperature and their relationships with digestibility. *Food Chemistry*, *358*, 129858. <https://doi.org/10.1016/j.foodchem.2021.129858>
- Ovando-Martínez, M., Sáyago-Ayerdi, S., Agama-Acevedo, E., Goñi, I., & Bello-Pérez, L. A. (2008). Unripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta. *Food Chemistry*, *113*(1), 121–126. <https://doi.org/10.1016/j.foodchem.2008.07.035>
- Owheruo, J. O., Edo, G. I., Bashir, Z. A., Akpogheli, P. O., & Agbo, J. J. (2023). Quality Evaluation of Breakfast Cereal Meal Produced from Finger Millet (*Eleusine coracana*) and Roasted African Yam Beans (*Sphenostylis stenocarpa*) Flour Blends. *Food Science and Engineering*, 182–190. <https://doi.org/10.37256/fse.4220232328>
- Oyeyinka, B. O., & Afolayan, A. J. (2020). Potentials of *Musa* Species Fruits against Oxidative Stress-Induced and Diet-Linked Chronic Diseases: In Vitro and In Vivo Implications of Micronutritional Factors and Dietary Secondary Metabolite Compounds. *Molecules*, *25*(21), 5036. <https://doi.org/10.3390/molecules25215036>
- Oyeyinka, S. A., Akintayo, O. A., Adebo, O. A., Kayitesi, E., & Njobeh, P. B. (2021). A review on the physicochemical properties of starches modified by microwave alone and in combination with other methods. *International Journal of Biological Macromolecules*, *176*, 87–95. <https://doi.org/10.1016/j.ijbiomac.2021.02.066>
- Padhi, S., & Dwivedi, M. (2022). Physico-chemical, structural, functional and powder flow properties of unripe green banana flour after the application of Refractance window drying. *Future Foods*, *5*, 100101. <https://doi.org/10.1016/j.fufo.2021.100101>

- Palframan, R., Gibson, G., & Rastall, R. (2003). Development of a quantitative tool for the comparison of the prebiotic effect of dietary oligosaccharides. *Letters in Applied Microbiology*, 37(4), 281–284. <https://doi.org/10.1046/j.1472-765x.2003.01398.x>
- Pandey, S., Kumar, A., & Rao, P. S. (2020). Optimization, modeling, and characterization study for the physicochemical properties of raw banana and defatted soy composite extrudates. *Food Chemistry*, 339, 127865. <https://doi.org/10.1016/j.foodchem.2020.127865>
- Pappalardo, G., & Lusk, J. L. (2016). The role of beliefs in purchasing process of functional foods. *Food Quality and Preference*, 53, 151–158. <https://doi.org/10.1016/j.foodqual.2016.06.009>
- Paramasivam, S. K., Saravanan, A., Narayanan, S., Shiva, K. N., Ravi, I., Mayilvaganan, M., Pushpa, R., & Uma, S. (2021). Exploring differences in the physicochemical, functional, structural, and pasting properties of banana starches from dessert, cooking, and plantain cultivars (*Musa* spp.). *International Journal of Biological Macromolecules*, 191, 1056–1067. <https://doi.org/10.1016/j.ijbiomac.2021.09.172>
- Pareek, S. (2016). Nutritional and Biochemical Composition of Banana (*Musa* spp.) Cultivars. In *Elsevier eBooks* (pp. 49–81). <https://doi.org/10.1016/b978-0-12-408117-8.00003-9>
- Park, J., Choi, I., & Kim, Y. (2015). Cookies formulated from fresh okara using starch, soy flour and hydroxypropyl methylcellulose have high quality and nutritional value. *Lebensmittel-Wissenschaft + Technologie/Food Science & Technology*, 63(1), 660–666. <https://doi.org/10.1016/j.lwt.2015.03.110>
- Pathare, P. B., & Al-Dairi, M. (2021). Effect of simulated vibration and storage on quality of tomato. *Horticulturae*, 7(11), 417. <https://doi.org/10.3390/horticulturae7110417>
- Pelissari, F. M., Andrade-Mahecha, M. M., Sobral, P. J. D. A., & Menegalli, F. C. (2012). Isolation and characterization of the flour and starch of plantain bananas (*Musa paradisiaca*). *Starch - Stärke*, 64(5), 382–391. <https://doi.org/10.1002/star.201100133>
- Pereira, A., & Maraschin, M. (2014). Banana (*Musa* spp) from peel to pulp: Ethnopharmacology, source of bioactive compounds and its relevance for human

- health. *Journal of Ethnopharmacology*, 160, 149–163. <https://doi.org/10.1016/j.jep.2014.11.008>
- Pereira, A., & Maraschin, M. (2014). Banana (*Musa* spp) from peel to pulp: Ethnopharmacology, source of bioactive compounds and its relevance for human health. *Journal of Ethnopharmacology*, 160, 149–163. <https://doi.org/10.1016/j.jep.2014.11.008>
- Pico, J., Xu, K., Guo, M., Mohamedshah, Z., Ferruzzi, M. G., & Martinez, M. M. (2019). Manufacturing the ultimate green banana flour: Impact of drying and extrusion on phenolic profile and starch bioaccessibility. *Food Chemistry*, 297, 124990. <https://doi.org/10.1016/j.foodchem.2019.124990>
- Plasek, B., Lakner, Z., Kasza, G., & Temesi, Á. (2019). Consumer evaluation of the role of functional food products in disease prevention and the characteristics of target groups. *Nutrients*, 12(1), 69. <https://doi.org/10.3390/nu12010069>
- Powthong, P., Jantrapanukorn, B., Suntornthiticharoen, P., & Laohaphatanalert, K. (2020). Study of prebiotic properties of selected banana species in Thailand. *Journal of Food Science and Technology*, 57(7), 2490–2500. <https://doi.org/10.1007/s13197-020-04284-x>
- Prasajak, P., Detchewa, P., Sriwichai, W., & Moongngarm, A. (2021). THE EFFECTS OF UNRIPE BANANA FLOUR ON RESISTANT STARCH CONTENT AND QUALITY CHARACTERISTICS OF GLUTEN-FREE RICE COOKIES. *Journal of Sustainability Science and Management*, 16(2), 67–78. <https://doi.org/10.46754/jssm.2021.02.008>
- Qadir, N., & Wani, I. A. (2023). Functional properties, antioxidant activity and in-vitro digestibility characteristics of brown and polished rice flours of Indian temperate region. *Grain & Oil Science and Technology*, 6(1), 43–57. <https://doi.org/10.1016/j.gaost.2022.12.001>
- Qamar, S., & Shaikh, A. (2018). Therapeutic potentials and compositional changes of valuable compounds from banana- A review. *Trends in Food Science & Technology*, 79, 1–9. <https://doi.org/10.1016/j.tifs.2018.06.016>

- Rabail, R., Sultan, M. T., Khalid, A. R., Sahar, A. T., Zia, S., Kowalczewski, P. Ł., Jeżowski, P., Shabbir, M. A., & Aadil, R. M. (2022). Clinical, nutritional, and functional evaluation of Chia Seed-Fortified muffins. *Molecules/Molecules Online/Molecules Annual*, 27(18), 5907. <https://doi.org/10.3390/molecules27185907>
- Radünz, M., Camargo, T. M., Nunes, C. F. P., Pereira, E. D. S., Ribeiro, J. A., Hackbart, H. C. D. S., Radünz, A. F. O., Radünz, A. L., Gularte, M. A., & Da Fonseca Barbosa, F. (2020). Gluten-free green banana flour muffins: chemical, physical, antioxidant, digestibility and sensory analysis. *Journal of Food Science and Technology*, 58(4), 1295–1301. <https://doi.org/10.1007/s13197-020-04638-5>
- Rahman, M. M., Rahaman, M. S., Islam, M. R., Rahman, F., Mithi, F. M., Alqahtani, T., Almikhlaifi, M. A., Alghamdi, S. Q., Alruwaili, A. S., Hossain, M. S., Ahmed, M., Das, R., Emran, T. B., & Uddin, M. S. (2021). Role of phenolic compounds in human disease: Current knowledge and future Prospects. *Molecules*, 27(1), 233. <https://doi.org/10.3390/molecules27010233>
- Rai, M. (2022). RTE versus RTC Food Products: A Practice Theory Perspective of ‘Meaning’ in Food Consumption: an abstract. In *Developments in marketing science: proceedings of the Academy of Marketing Science* (pp. 459–460). https://doi.org/10.1007/978-3-030-95346-1_154
- Ranganna, S. (1997). *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. (2nd ed.). Tata McGraw Hill Publishing Company Limited, New Delhi.
- Rao, B. D., Kulkarni, D. B., & Kavitha, C. (2018). Study on evaluation of starch, dietary fiber and mineral composition of cookies developed from 12 sorghum cultivars. *Food Chemistry*, 238, 82–86. <https://doi.org/10.1016/j.foodchem.2016.12.069>
- Ratnasari, D., Rustanti, N., Arifan, F., & Afifah, D. (2018). The Effects of Treatments on Batu Banana Flour and Percentage of Wheat Substitution on The Resistant Starch, In Vitro Starch Digestibility Content and Palatability of Cookies Made with Banana (*Musa balbisiana* Colla) Flour. *IOP Conference Series Earth and Environmental Science*, 116, 012003. <https://doi.org/10.1088/1755-1315/116/1/012003>
- Raungrusmee, S., Shrestha, S., Sadiq, M. B., & Anal, A. K. (2020). Influence of resistant starch, xanthan gum, inulin and defatted rice bran on the physicochemical, functional and sensory properties of low glycemic gluten-free noodles. *Lebensmittel-*

- Wissenschaft + Technologie/Food Science & Technology*, 126, 109279.
<https://doi.org/10.1016/j.lwt.2020.109279>
- Raveena, N. K., Ingaladal, N., Reshma, M., & Lankalapalli, R. S. (2022). Phytochemical investigation of unripe banana (Musa AAB) cv. Nendran and its novel 'Banana Grits.' *Food Chemistry Advances*, 1, 100063. <https://doi.org/10.1016/j.focha.2022.100063>
- Ravi, I., & Mustaffa, M. M. (2013). Starch and amylose variability in banana cultivars. *Indian Journal of Plant Physiology*, 18(1), 83–87. <https://doi.org/10.1007/s40502-013-0014-2>
- Ray. (2021). *Banana production and handling*. Gopal Narayan Singh University, India.
- Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine*, 26(9–10), 1231–1237. [https://doi.org/10.1016/s0891-5849\(98\)00315-3](https://doi.org/10.1016/s0891-5849(98)00315-3)
- Reddy, C. K., Haripriya, S., & Vidya, P. V. (2015). Morphology, physico-chemical and functional characteristics of starches from different banana cultivars. *Journal of Food Science and Technology*, 52(11), 7289–7296. <https://doi.org/10.1007/s13197-015-1809-0>
- Rezai, G., Teng, P. K., Mohamed, Z., & Shamsudin, M. N. (2014). Structural equation modeling of consumer purchase intention toward synthetic functional foods. *Journal of Food Products Marketing*, 20(sup1), 13–34. <https://doi.org/10.1080/10454446.2014.921868>
- Riaz, M., Khalid, R., Afzal, M., Anjum, F., Fatima, H., Zia, S., Rasool, G., Egbuna, C., Mtewa, A. G., Uche, C. Z., & Aslam, M. A. (2023). Phytobioactive compounds as therapeutic agents for human diseases: A review. *Food Science & Nutrition*, 11(6), 2500–2529. <https://doi.org/10.1002/fsn3.3308>
- Rosado, C. P., Rosa, V. H. C., Martins, B. C., Soares, A. C., Almo, A., Monteiro, E. B., Da Rocha Pinheiro Mulder, A., Moura-Nunes, N., & Daleprane, J. B. (2021). Green banana flour supplementation improves obesity-associated systemic inflammation and regulates gut microbiota profile in mice fed high-fat diets. *Applied Physiology*,

- Nutrition, and Metabolism*, 46(12), 1469–1475. <https://doi.org/10.1139/apnm-2021-0288>
- Ruíz-Capillas, C., & Herrero, A. M. (2021). Sensory analysis and consumer research in new product development. *Foods*, 10(3), 582. <https://doi.org/10.3390/foods10030582>
- Sadasivam S, & Manickam A. (2008). *Biochemical Methods*. (3rd edition.). New Age International.
- Safraid, G. F., Portes, C. Z., Dantas, R. M., & Batista, Â. G. (2024). Perception of functional food consumption by adults: Is there any difference between generations? *Brazilian Journal of Food Technology/Brazilian Journal of Food Technology*, 27. <https://doi.org/10.1590/1981-6723.09523>
- Sahu, S., Kumar, S., Nagtode, N. R., & Sahu, M. (2024). “The burden of lifestyle diseases and their impact on health service in India”—A narrative review. *Journal of Family Medicine and Primary Care*, 13(5), 1612–1619. https://doi.org/10.4103/jfmpe.jfmpe_693_23
- Salazar, D., Arancibia, M., Calderón, L., López-Caballero, M., & Montero, M. (2021). Underutilized Green Banana (*Musa acuminata* AAA) Flours to Develop Fiber Enriched Frankfurter-Type Sausages. *Foods*, 10(5), 1142. <https://doi.org/10.3390/foods10051142>
- Salvador, A., Sanz, T., & Fiszman, S. (2007). Changes in colour and texture and their relationship with eating quality during storage of two different dessert bananas. *Postharvest Biology and Technology*, 43(3), 319–325. <https://doi.org/10.1016/j.postharvbio.2006.10.007>
- Santi, E. N., Murdianto, W., Ahmadi, N. R., Waryat, N., & Sulistyningrum, A. (2022). Physicochemical Characteristics of Three Local Sweet Potato Flour from East Kalimantan. *IOP Conference Series Earth and Environmental Science*, 1024(1), 012037. <https://doi.org/10.1088/1755-1315/1024/1/012037>
- Sarawong, C., Schoenlechner, R., Sekiguchi, K., Berghofer, E., & Ng, P. K. W. (2014). Effect of extrusion cooking on the physicochemical properties, resistant starch,

- phenolic content and antioxidant capacities of green banana flour. *Food Chemistry*, *143*, 33–39. <https://doi.org/10.1016/j.foodchem.2013.07.081>
- Sardá, F. a. H., De Lima, F. N., Lopes, N. T., De O Santos, A., De Castro Tobaruela, E., Kato, E. T. M., & De Menezes, E. W. (2016). Identification of carbohydrate parameters in commercial unripe banana flour. *Food Research International*, *81*, 203–209. <https://doi.org/10.1016/j.foodres.2015.11.016>
- Savlak, N., Türker, B., & Yeşilkanat, N. (2016). Effects of particle size distribution on some physical, chemical and functional properties of unripe banana flour. *Food Chemistry*, *213*, 180–186. <https://doi.org/10.1016/j.foodchem.2016.06.064>
- Segundo, C. N., Román, L., Gómez, M., & Martínez, M. M. (2017). Mechanically fractionated flour isolated from green bananas (*M. cavendishii* var. *nanica*) as a tool to increase the dietary fiber and phytochemical bioactivity of layer and sponge cakes. *Food Chemistry*, *219*, 240–248. <https://doi.org/10.1016/j.foodchem.2016.09.143>
- Setyawan, N., Maninang, J. S., Suzuki, S., & Fujii, Y. (2021). Variation in the Physical and Functional Properties of Yam (*Dioscorea* spp.) Flour Produced by Different Processing Techniques. *Foods*, *10*(6), 1341. <https://doi.org/10.3390/foods10061341>
- Shaikh, J. R., & Patil, M. (2020). Qualitative tests for preliminary phytochemical screening: An overview. *International Journal of Chemical Studies*, *8*(2), 603–608. <https://doi.org/10.22271/chemi.2020.v8.i2i.8834>
- Shareenie, M. A., Matkhir, A. A., Akanda, J. H., Mamat, H., & Hamid, M. A. (2021). The effects of unripe Saba banana composite flour on acceptance and physicochemical characteristics of biscuits. *Scientific Research Journal*, *18*(1), 55. <https://doi.org/10.24191/srj.v18i1.11397>
- Shini, V. S., Billu, A., Suvachan, A., & Nisha, P. (2024). Exploring the nutritional, physicochemical and hypoglycemic properties of green banana flours from unexploited banana cultivars of Southern India. *Sustainable Food Technology*, *2*(4), 1113–1127. <https://doi.org/10.1039/d4fb00066h>
- Sidhu, J. S., & Zafar, T. A. (2020). Chemical Composition and Nutritional Profile of Raw and Processed Banana Products. In *In Handbook of Banana Production, Postharvest*

- Science, Processing Technology, and Nutrition* (pp. 207–225).
<https://doi.org/10.1002/9781119528265.ch11>
- Silva, C. R., Simoni, J. A., Collins, C. H., & Volpe, P. L. O. (1999). Ascorbic acid as a standard for iodometric titrations. An analytical experiment for general chemistry. *Journal of Chemical Education*, 76(10), 1421. <https://doi.org/10.1021/ed076p1421>
- Singh, R., Singh, K., Nain, M. S., & Singh, R. (2020a). Storage stability of popped pearl millet based ready to eat breakfast cereal. *The Indian Journal of Agricultural Sciences*, 90(10), 1915–1920. <https://doi.org/10.56093/ijas.v90i10.107902>
- Singh, S., & Sagar, R. (2021). A critical look at online survey or questionnaire-based research studies during COVID-19. *Asian Journal of Psychiatry*, 65, 102850. <https://doi.org/10.1016/j.ajp.2021.102850>
- Singla, V., & Chakkaravarthi, S. (2017). Applications of prebiotics in food industry: A review. *Food Science and Technology International*, 23(8), 649–667. <https://doi.org/10.1177/1082013217721769>
- Singleton, V.L., & Slinkard, K. (1977). Total phenol analysis: Automation and comparison with manual methods. *Am J Enol Vitic*, 2849–2855.
- Sissons, M. (2022). Development of Novel Pasta Products with Evidence Based Impacts on Health—A Review. *Foods*, 11(1), 123. <https://doi.org/10.3390/foods11010123>
- Soares, C. A., Peroni-Okita, F. H. G., Cardoso, M. B., Shitakubo, R., Lajolo, F. M., & Cordenunsi, B. R. (2011). Plantain and banana starches: granule structural characteristics explain the differences in their starch degradation patterns. *Journal of Agricultural and Food Chemistry*, 59(12), 6672–6681. <https://doi.org/10.1021/jf201590h>
- Sorescu, A., Nuta, A., Ion, R., & Iancu, L. (2018). Qualitative Analysis of Phytochemicals from Sea Buckthorn and Gooseberry. In *InTech eBooks*. <https://doi.org/10.5772/intechopen.77365>
- Sparke, K., & Menrad, K. (2009). Cross-European and functional Food-Related consumer segmentation for new product development. *Journal of Food Products Marketing*, 15(3), 213–230. <https://doi.org/10.1080/10454440902908142>

- Steinhauser, J. P., & Hamm, U. (2018). Consumer and product-specific characteristics influencing the effect of nutrition, health and risk reduction claims on preferences and purchase behavior – A systematic review. *Appetite*, *127*, 303–323. <https://doi.org/10.1016/j.appet.2018.05.012>
- Sugiharto, S., Rahmawati, O. M., Yudiarti, T., Widiastuti, E., Wahyuni, H. I., Sartono, T. A., Agusetyaningsih, I., & Ayaşan, T. (2023). The use of unripe banana flour as a functional feed ingredient on blood profile, serum biochemical and intestinal indices of broilers. *The Open Agriculture Journal*, *17*(1). <https://doi.org/10.2174/18743315-v17-e230110-2022-44>
- Sulung, N. K., Aziss, N. S. M., Kutbi, N. F., Ahadaali, A. A., Zairi, N. A., Mahmud, I. I., Sajak, A. a. B., Sultana, S., & Azlan, A. (2023). Validation of in vitro glycaemic index (eGI) and glycaemic load (eGL) based on selected baked products, beverages, and canned foods. *Food Chemistry Advances*, *3*, 100502. <https://doi.org/10.1016/j.focha.2023.100502>
- Suntharalingam, S., & Ravindran, G. (1993). Physical and biochemical properties of green banana flour. *Plant Foods for Human Nutrition*, *43*(1), 19–27. <https://doi.org/10.1007/bf01088092>
- Suriya, M., Rajput, R., Reddy, C. K., Haripriya, S., & Bashir, M. (2017). Functional and physicochemical characteristics of cookies prepared from *Amorphophallus paeoniifolius* flour. *Journal of Food Science and Technology*, *54*(7), 2156–2165. <https://doi.org/10.1007/s13197-017-2656-y>
- Szakály, Z., Kovács, S., Pető, K., Huszka, P., & Kiss, M. (2019). A modified model of the willingness to pay for functional foods. *Appetite*, *138*, 94–101. <https://doi.org/10.1016/j.appet.2019.03.020>
- Tangthanantorn, J., Wichienchot, S., & Sirivongpaisal, P. (2021). Development of fresh and dried noodle products with high resistant starch content from banana flour. *Food Science and Technology*, *42*. <https://doi.org/10.1590/fst.68720>
- Temesi, Á., Bacsó, Á., Grunert, K. G., & Lakner, Z. (2019). Perceived correspondence of health effects as a new determinant influencing purchase intention for functional food. *Nutrients*, *11*(4), 740. <https://doi.org/10.3390/nu11040740>

- Temgire, S., Borah, A., Kumthekar, S., & Idate, A. (2021). Recent trends in ready to eat/cook food products: A review. *The Pharma Innovation*, *10*(5), 211–217. <https://doi.org/10.22271/tpi.2021.v10.i5c.6207>
- Thakur, P., Pawar, V., & Shere, D. (2016). Material balance, proximate and functional analysis of green banana flour prepared by cabinet drying method. *FOOD SCIENCE RESEARCH JOURNAL*, *7*(2), 190–194. <https://doi.org/10.15740/has/fsrj/7.2/190-194>
- Thanyapanich, N., Jimtaisong, A., & Rawdkuen, S. (2021). Functional Properties of Banana Starch (*Musa* spp.) and Its Utilization in Cosmetics. *Molecules*, *26*(12), 3637. <https://doi.org/10.3390/molecules26123637>
- Thompson, M. S., Yan, T. H., Saari, N., & Sarbini, S. R. (2022). A review: Resistant starch, a promising prebiotic for obesity and weight management. *Food Bioscience*, *50*, 101965. <https://doi.org/10.1016/j.fbio.2022.101965>
- Tian, D., Xu, X., Peng, Q., Zhang, Y., Zhang, P., Qiao, Y., & Shi, B. (2020). Effects of banana powder (*Musa acuminata* Colla) on the composition of human fecal microbiota and metabolic output using in vitro fermentation. *Journal of Food Science*, *85*(8), 2554–2564. <https://doi.org/10.1111/1750-3841.15324>
- Topolska, K., Florkiewicz, A., & Filipiak-Florkiewicz, A. (2021). Functional Food—Consumer Motivations and Expectations. *International Journal of Environmental Research and Public Health/International Journal of Environmental Research and Public Health*, *18*(10), 5327. <https://doi.org/10.3390/ijerph18105327>
- Tyl, C., & Sadler, G. D. (2017). pH and Titratable Acidity. In *Food science text series* (pp. 389–406). https://doi.org/10.1007/978-3-319-45776-5_22
- Uma, & Sathiamoorthy. (2002). *Names and synonyms of bananas and plantains of India*. National Research Center for Banana (ICAR). <https://www.musalit.org/seeMore.php?id=7263>
- Uma, S., Kalpana, S., Sathiamoorthy, S., & Kumar, V. (2005). Evaluation of commercial cultivars of banana. *Noticiario De Recursos Fitogenéticos. Plant Genetic Resources Newsletter- FAO and IPGRI*, *142*, 29. https://cgspace.cgiar.org/bitstream/handle/10568/104992/Plant_Genetic_Resources_Newsletter_No_142.pdf?sequence=3#page=31

- Urala, N., Arvola, A., & Lähteenmäki, L. (2003). Strength of health-related claims and their perceived advantage. *International Journal of Food Science & Technology*, 38(7), 815–826. <https://doi.org/10.1046/j.1365-2621.2003.00737.x>
- USDA *FoodData Central*. (n.d.). <https://fdc.nal.usda.gov/>
- Vahdat, M., Hosseini, S. A., Mohseni, G. K., Heshmati, J., & Rahimlou, M. (2020). Effects of resistant starch interventions on circulating inflammatory biomarkers: a systematic review and meta-analysis of randomized controlled trials. *Nutrition Journal*, 19(1). <https://doi.org/10.1186/s12937-020-00548-6>
- Venkataramani, K. S. (1946). Studies on Indian bananas. *Proceedings / Indian Academy of Sciences*, 23(3), 113–128. <https://doi.org/10.1007/bf03049665>
- Venn, B. J., Kataoka, M., & Mann, J. (2014). The use of different reference foods in determining the glycemic index of starchy and non-starchy test foods. *Nutrition Journal*, 13(1). <https://doi.org/10.1186/1475-2891-13-50>
- Vernaza, M. G., Gularte, M. A., & Chang, Y. K. (2011). Addition of green banana flour to instant noodles: rheological and technological properties. *Ciência E Agrotecnologia*, 35(6), 1157–1165. <https://doi.org/10.1590/s1413-70542011000600016>
- Verneau, N., La Barbera, N., & Furno, N. (2019). The Role of Health Information in Consumers' Willingness to Pay for Canned Crushed Tomatoes Enriched with Lycopene. *Nutrients*, 11(9), 2173. <https://doi.org/10.3390/nu11092173>
- Vlachos, D., Malisova, S., Lindberg, F. A., & Karaniki, G. (2020). Glycemic Index (GI) or Glycemic Load (GL) and Dietary Interventions for Optimizing Postprandial Hyperglycemia in Patients with T2 Diabetes: A Review. *Nutrients*, 12(6), 1561. <https://doi.org/10.3390/nu12061561>
- Von Loesecke, H. W. (1950). *Bananas: chemistry, physiology, technology*. Interscience Publishers No. 634.772/V947.
- Vu, H. T., Scarlett, C. J., & Vuong, Q. V. (2017). Phenolic compounds within banana peel and their potential uses: A review. *Journal of Functional Foods*, 40, 238–248. <https://doi.org/10.1016/j.jff.2017.11.006>
- Wang, J., Tang, X. J., Chen, P. S., & Huang, H. H. (2014). Changes in resistant starch from two banana cultivars during postharvest storage. *Food Chemistry*, 156, 319–325. <https://doi.org/10.1016/j.foodchem.2014.02.012>

- Wang, S., Li, C., Copeland, L., Niu, Q., & Wang, S. (2015). Starch Retrogradation: A Comprehensive review. *Comprehensive Reviews in Food Science and Food Safety*, 14(5), 568–585. <https://doi.org/10.1111/1541-4337.12143>
- Wang, Z., Miao, H., Liu, J., Xu, B., Yao, X., Xu, C., Zhao, S., Fang, X., Jia, C., Wang, J., Zhang, J., Li, J., Xu, Y., Wang, J., Ma, W., Wu, Z., Yu, L., Yang, Y., Liu, C., . . . Jin, Z. (2019). *Musa balbisiana* genome reveals subgenome evolution and functional divergence. *Nature Plants*, 5(8), 810–821. <https://doi.org/10.1038/s41477-019-0452-6>
- Wani, I. A., Sogi, D. S., Wani, A. A., Gill, B. S., & Shivhare, U. S. (2010). Physico-chemical properties of starches from Indian kidney bean (*Phaseolus vulgaris*) cultivars. *International Journal of Food Science & Technology*, 45(10), 2176–2185. <https://doi.org/10.1111/j.1365-2621.2010.02379.x>
- Wani, I. A., Wani, A. A., Gani, A., Muzzaffar, S., Gul, M. K., Masoodi, F. A., & Wani, T. A. (2015). Effect of gamma-irradiation on physico-chemical and functional properties of arrowhead (*Sagittaria sagittifolia* L.) tuber flour. *Food Bioscience*, 11, 23–32. <https://doi.org/10.1016/j.fbio.2015.04.003>
- Wardle, J., Parmenter, K., & Waller, J. (2000). Nutrition knowledge and food intake. *Appetite*, 34(3), 269–275. <https://doi.org/10.1006/appe.1999.0311>
- Wen, J., Li, M., Hu, J., Tan, H., & Nie, S. (2022). Resistant starches and gut microbiota. *Food Chemistry*, 387, 132895. <https://doi.org/10.1016/j.foodchem.2022.132895>
- Wolever, T., Jenkins, D., Jenkins, A., & Josse, R. (1991). The glycemic index: methodology and clinical implications. *American Journal of Clinical Nutrition*, 54(5), 846–854. <https://doi.org/10.1093/ajcn/54.5.846>
- Wong, T. H. T., & Louie, J. C. Y. (2016). The relationship between resistant starch and glycemic control: A review on current evidence and possible mechanisms. *Starch - Stärke*, 69(7–8). <https://doi.org/10.1002/star.201600205>
- Xu, J., Ma, Z., Li, X., Liu, L., & Hu, X. (2020). A more pronounced effect of type III resistant starch vs. type II resistant starch on ameliorating hyperlipidemia in high fat diet-fed mice is associated with its supramolecular structural characteristics. *Food & Function*, 11(3), 1982–1995. <https://doi.org/10.1039/c9fo02025j>

- Yadav, B. S., Yadav, R. B., Kumari, M., & Khatkar, B. S. (2014). Studies on suitability of wheat flour blends with sweet potato, colocasia and water chestnut flours for noodle making. *Lebensmittel-Wissenschaft + Technologie/Food Science & Technology*, 57(1), 352–358. <https://doi.org/10.1016/j.lwt.2013.12.042>
- Yang, Z., Zhang, Y., Wu, Y., & Ouyang, J. (2022). Factors influencing the starch digestibility of starchy foods: A review. *Food Chemistry*, 406, 135009. <https://doi.org/10.1016/j.foodchem.2022.135009>
- Ye, J., Hu, X., Luo, S., McClements, D. J., Liang, L., & Liu, C. (2018). Effect of endogenous proteins and lipids on starch digestibility in rice flour. *Food Research International*, 106, 404–409. <https://doi.org/10.1016/j.foodres.2018.01.008>
- Yu, A. H. M., Phoon, P. Y., Ng, G. C. F., & Henry, C. J. (2020). Physicochemical characteristics of green banana flour and its use in the development of konjac-green banana noodles. *Journal of Food Science*, 85(10), 3026–3033. <https://doi.org/10.1111/1750-3841.15458>
- Zambrano, M. V., Dutta, B., Mercer, D. G., MacLean, H. L., & Touchie, M. F. (2019). Assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: A review. *Trends in Food Science & Technology*, 88, 484–496. <https://doi.org/10.1016/j.tifs.2019.04.006>
- Zandonadi, R. P., Botelho, R. B. A., Gandolfi, L., Ginani, J. S., Montenegro, F. M., & Pratesi, R. (2012). Green Banana Pasta: an alternative for Gluten-Free diets. *Journal of the Academy of Nutrition and Dietetics*, 112(7), 1068–1072. <https://doi.org/10.1016/j.jand.2012.04.002>
- Zhang, S., Zhao, K., Xu, F., Chen, X., Zhu, K., Zhang, Y., & Xia, G. (2023). Study of unripe and inferior banana flours pre-gelatinized by four different physical methods. *Frontiers in Nutrition*, 10. <https://doi.org/10.3389/fnut.2023.1201106>
- Zheng, Y., Wang, Q., Li, B., Lin, L., Tundis, R., Loizzo, M., Zheng, B., & Xiao, J. (2016). Characterization and Prebiotic Effect of the Resistant Starch from Purple Sweet Potato. *Molecules*, 21(7), 932. <https://doi.org/10.3390/molecules21070932>
- <https://www.crop-diversity.org/mgis5/cultivar-group-catalogue/peyan>
- http://www.agritech.tnau.ac.in/expert_system/banana/season&variety.html

Appendix I
Ethical Certificate

Universal Ethics Committee
CDSCO Reg No. ECR/125/Ind/TN/2013
OHRP Registration No. IORG0007234
An ISO 9001:2008 Certified Ethics Committee

To 13-Jan-20
Mrs. A. Haripriya,
Reg No 18PHFDP005
PhD Research Scholar (Part Time)
#25/1 Lakshmi Colony, T. Nagar, Chennai 600017


Dear Mrs. A. Haripriya,

Sub: Approval Letter for PhD Thesis – reg

The Independent Ethics Committee - Universal Ethics Committee reviewed and discussed your application to conduct the PhD Thesis entitled "*Formulation and Evaluation of Functional Carbohydrate-Unripe Banana Flour Based RTE and RTC Foods*" on **10-Jan-20**.

The following documents were reviewed:

1. Thesis Study Plan
2. Informed Consent Document
3. Purchase Intent Form
4. Sensory Evaluation Sheet
5. PhD Registration : Mrs. A. Haripriya



1 of 2

Web : www.auroushealthcare.com E-mail : universalethicscommittee@gmail.com

Universal Ethics Committee

COSCO Reg No. ECR/125/Indi/TN/2013
OHRP Registration No. IORG0007234
An ISO 9001:2008 Certified Ethics Committee

The following members of the ethics committee were present at the meeting held on
Date : 10-Jan-20
Time : 05:00 PM to 05:35 PM
Venue: Conference Hall, #180/109, G2, RR Villa,
 Rangarajapuram Main Road, Kodambakkam, Chennai - 600024

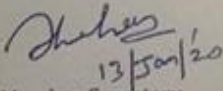
S.No	NAME OF THE MEMBER	GENDER	QUALIFICATION	DESIGNATION/ROLE OF MEMBER IN UEC
1.	Mr. S.B. Viswanathan	Male	B.B.A., M.L	Chairman
2.	Dr. V. T. Sriraam	Male	MBBS, MD (Pharmacology)	Basic Medical Scientist/ Medical Pharmacologist
3.	Dr. S. Stalin	Male	MBBS, MD,DCH	Clinician/ Paediatrician
4.	Mrs. G. Kamatchi Lakshmi	Female	B.Sc. Computer Science	Lay Person
5.	Mr.E. MuthuNarayanaMoorthy	Male	B.Sc.; LLB	Legal Expert
6.	Mr. M. M. Saravanan	Male	B. Com ;Dip Cooperation	Lay Person
7.	Mr. J. Thiagarajan	Male	10 th Standard	Theologian
8.	Mr. A. Chakravarthy	Male	B.Sc, MA, PGDLA, CAIB	Member Secretary


The applicant is a PhD research Scholar (Part Time) of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore. She confirms that the study will be conducted in Chennai.

We render our full board approval for this study

UEC expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and subject information/informed consent and asks to be provided a copy of the final report.

Yours sincerely,


 13/Jan/20
 Member Secretary
 Universal Ethics Committee



E-mail : universalethicscommittee@gmail.com
 Web : www.auroushealthcare.com

2 of 2

Appendix II

Questionnaire - KAP study on Functional foods









Dear Participant,









As part of my PhD research study on the knowledge, attitudes, and practices regarding functional foods and nutraceuticals, I kindly request you to answer the following questions. Your participation will provide valuable insights and greatly contribute to the success of this research. Please be assured that all personal details provided will remain confidential.









Thank you for your time and support



1. Name _____
2. Area of residence _____
3. Age: 20- 25 years/ 26-40 years/ 41-50 years
4. Gender: Male/ Female
5. Occupation _____
6. Educational Qualification
 - a. Higher Secondary
 - b. Graduation
 - c. Post-Graduation / Higher
7. Household Income per month
 - a. Below 30000
 - b. Rs 30000- Rs 50000
 - c. Rs 50000- Rs 100000
 - d. Above Rs 100000
8. Type of family: Joint / Nuclear
9. Number of family members _____
10. Are you a?
 - a) Vegetarian b) Non-Vegetarian c) Others
11. Do your family members or yourselves suffer from any of the following health problems?
 - a. Diabetes Mellitus b. Cardiovascular problem c. Obesity d. Hypothyroidism
 - e. Kidney disease f. Others specify
12. Are you aware of the term functional foods/ nutraceuticals?
 - a. Yes, I am aware
 - b. No, I don't know
13. What explanation best refers to functional foods?
 - a. Food with a specific benefit above the nutrients it naturally contains
 - b. Healthy foods
 - c. Artificial foods
 - d. Genetically modified foods
 - e. Don't know
14. Which of the following foods are considered to be functional foods?

Read the list of foods given below and tick yes or no for each food item

<p>Almonds</p> 	<p>Yes/No</p>	<p>Pumpkin seeds</p> 	<p>Yes/No</p>
<p>Walnuts</p> 	<p>Yes/No</p>	<p>Legumes</p> 	<p>Yes/No</p>
<p>Basil seeds</p> 	<p>Yes/No</p>	<p>Soy proteins</p> 	<p>Yes/No</p>
<p>Chia seeds</p> 	<p>Yes/No</p>	<p>Whole grains</p> 	<p>Yes/No</p>

<p>Flax seeds</p> 	<p>Yes/No</p>	<p>Citrus fruits</p> 	<p>Yes/No</p>
<p>Green leafy vegetables</p> 	<p>Yes/No</p>	<p>Broccoli, cabbage, cauliflower</p> 	<p>Yes/No</p>
<p>Berries</p> 	<p>Yes/No</p>	<p>Onion</p> 	<p>Yes/No</p>
<p>Apples</p> 	<p>Yes/No</p>	<p>Garlic</p> 	<p>Yes/No</p>

<p>Turmeric</p> 	<p>Yes/No</p>	<p>Ginger</p> 	<p>Yes/No</p>
<p>Curd</p> 	<p>Yes/No</p>	<p>Black Pepper</p> 	<p>Yes/No</p>
<p>Dark chocolate</p> 	<p>Yes/No</p>	<p>Fish</p> 	<p>Yes/No</p>
<p>Grapes</p> 	<p>Yes/No</p>	<p>Green and black tea</p> 	<p>Yes/No</p>

<p>Red wine</p> 	<p>Yes/No</p>	<p>Raw bananas, Sweet Potato</p> 	<p>Yes/No</p>
<p>Don't Know functional foods</p>			

15. What are the health benefits of functional foods?
 - a. Reduced risk of hypertension and heart disease
 - b. Reduced risk of Diabetes and Better blood sugar management
 - c. Reduced risk of obesity or weight gain
 - d. Cancer prevention
 - e. Better bone health
 - f. Immune boosting
 - g. Improved performance
 - h. Gain satisfaction
 - i. Maintain good health
 - j. Don't know
16. How did you get to know about functional foods or nutraceuticals?
 - a. Dietitians
 - b. Physicians
 - c. Food labels
 - d. Newspapers, magazines and/or books
 - e. Family and/or friends
 - f. Advertisements
 - g. Internet
17. Do you think it's important to add functional foods in our diet each day?
 - a. No
 - b. Not sure
 - c. Yes
18. How good do you think on health promoting and disease prevention role of functional foods?
 - a. Not good
 - b. Not sure
 - c. Good
19. How confident do you feel about the safety of functional foods and nutraceuticals?
 - a. Not confident
 - b. Ok/so-so
 - c. Confident

20. Some people think, if used in excess, functional foods can be harmful to health. Do you agree with it?
- Agree
 - Not sure/ Neutral
 - Disagree
21. Are you willing to pay a higher price for functional foods as compared to conventional ones?
- No
 - Not sure
 - Yes
22. Do you like the incorporation of functional ingredients in commonly consumed ready to eat foods?
- No
 - Neutral
 - Yes
23. Are you likely to compromise on the taste of food for the sake of health?
- No
 - Yes
- 24. I would like to ask you about particular foods you may eat on their own or as part of a dish. Yesterday, during the day and night, did you consume any of the following foods?**
Read the list of foods given below and tick yes or no for each food item.
- Juices with added vitamins and minerals: Yes / No
 - Probiotic yoghurt: Yes / No
 - Probiotic fruit juices: Yes / No
 - High fibre cereals with Psyllium /Oat bran: Yes / No
 - High fibre biscuits/ cookies: Yes / No
 - Fortified milk: Yes / No
 - Low fat cheese/margarine/ butter: Yes / No
 - Low salt products: Yes / No
 - Green tea: Yes / No
 - Snack bar with added fibre: Yes / No
 - Energy drinks with sugar replacers: Yes / No
 - Beverages with herbal blends: Yes / No
 - Wheat/ milletbased noodles, pasta: Yes / No
 - Sweets and chewing gums with sugar replacers: Yes / No
- 25. I would like to ask you about particular nutrient or dietary supplements you may you consume usually or those which you consumed within last 7 days**
Read the list of supplements given below and tick yes or no for each food item.
- Garlic pills: Yes / No
 - Cod liver oil: Yes / No
 - Omega 3 fatty acids: Yes / No
 - Beta glucan: Yes / No
 - Creatinine: Yes / No
 - Carnitine: Yes / No
 - Lipoic acid: Yes / No
 - Calcium: Yes / No
 - Probiotics: Yes / No

- j. Inulin: Yes / No
 - k. Arabinogalactan: Yes / No
 - l. Arabinoxylan: Yes / No
 - m. Fructo oligosaccharides: Yes / No
 - n. Beta carotene capsules: Yes / No
 - o. Zinc / Chromium: Yes / No
 - p. Isoflavones: Yes / No
 - q. Herbs like Echinacea / Fenugreek / Ginseng: Yes / No
26. Do you read the health claim / nutrient label of the food products before making a choice to buy?
- a. Yes
 - b. No
27. Indicate which nutrients, when mentioned in a nutrient content claim on a functional food product, would increase your consumption of the product.
- a. Salt/sodium
 - b. Dietary fibre
 - c. Omega-3 fatty acids
 - d. Low fat
 - e. Low calories
 - f. Any other, Specify _____
 - g. None of these foods

Appendix III



சித்த மருத்துவ மைய ஆராய்ச்சி நிலையம்
மத்திய சித்த மருத்துவ ஆராய்ச்சிக் குழுமம், ஆயுஷ் அமைச்சகம், இந்திய அரசு)

सिद्ध केंद्रीय अनुसन्धान संस्थान
(सी.सी.आर.एस., चेन्नई, आयुष मंत्रालय, भारत सरकार),
अण्णा सरकारी अस्पताल परिसर, अरुम्बाक्कम, चेन्नई - 600106
SIDDHA CENTRAL RESEARCH INSTITUTE

(Central Council for Research in Siddha, Chennai, Ministry of AYUSH, Government of India)
Anna Govt. Hospital Campus, Arumbakkam, Chennai – 600106,

E-mail: crisiddha@gmail.com/stores.cris@gmail.com/Phone: 044-26214925, 26214809, Web: <http://crisiddha.tn.nic.in>

Form No. PCOG002-ACF

24.05.2023

AUTHENTICATION CERTIFICATE FOR 529.15052301-02

Certified that the sample submitted by A. Haripriya, Research Scholar, Avinashilingam Institute for Home science and Higher Education for Women was identified as:

Code	Botanical Name	Tamil Name	Part
M15052301P	<i>Musa × paradisiaca</i> L.	Peyen	Fruit
M15052302P	<i>Musa × paradisiaca</i> L.	Monthan	Fruit



M15052301P



M15052302P

* WFO (2023): *Musa × paradisiaca* L. Published on the Internet: <http://www.worldfloraonline.org/taxon/wfo-0000474656>; Accessed on: 24 May 2023


Dr. K.N. Sunil Kumar 24/5/23
Research Officer/Sci-II and HOD
Department of Pharmacognosy
சி.கே.எஸ். சூனிள் குமார்/Dr. K.N. Sunil Kumar
ஆயுஷ் அமைச்சர் (அரசியல்துறை)/AYUSH(Pharmacognosy)
மருத்துவ ஆயுஷ் அமைச்சகம்,
(சி.சி.ஆர்.எஸ். நேர்வ., அரூம்பாக்கம், சென்னை)
அணா அரசாங்கி அஸ்ப்தால் சி.ஓ.பி., அரூம்பாக்கம், சென்னை-600106
SIDDHA CENTRAL RESEARCH INSTITUTE
Central Council for Research in Siddha, Ministry of AYUSH, Govt. of India
Anna Govt. Hospital Campus, Arumbakkam, Chennai - 600106


Dr. R. Ganesan
Asst. Director-Biochemistry
(Sci-III/In-charge)
சி.சி.ஆர்.எஸ். நேர்வ., அரூம்பாக்கம், சென்னை
அணா அரசாங்கி அஸ்ப்தால் சி.ஓ.பி., அரூம்பாக்கம், சென்னை-600106
SIDDHA CENTRAL RESEARCH INSTITUTE
Central Council for Research in Siddha, Ministry of AYUSH, Govt. of India
Anna Govt. Hospital Campus, Arumbakkam, Chennai - 600106

Appendix IV

Relative ranking of flow by compressibility index and Hausner ratio* (Alam et al., 2023)

Flowability expected	Hausner Ratio	Carr Index
Excellent / Very Free Flow	1.00 - 1.11	≤10
Good / Free Flow	1.12 - 1.18	11-15
Fair	1.19 - 1.25	16-20
Passable	1.26 - 1.34	21-25
Poor Flow / Cohesive	1.35 - 1.45	26-31
Very Poor Flow / Very Cohesive	1.46 - 1.59	32-37
Approximatively no flow	≥ 1.60	≥ 38

Determination of Starch Composition

Determination of Total Starch

The total starch content in the formulated UBF samples was determined enzymatically following the method of Goni et al. (1997). A 50 mg sample was dispersed in 6 mL of 2 M KOH and homogenized for 30 minutes at room temperature. The resulting suspension was treated with 0.4 M sodium acetate buffer (pH 4.75) and 60 μ L of amyloglucosidase (A7095, Sigma-Aldrich) and incubated at 60 °C for 45 minutes in a shaking water bath.

The starch content, expressed as glucose, was measured using the glucose oxidase-peroxidase (GOD POD) kit. A conversion factor of 0.9 was applied to convert glucose to starch.

Determination of Resistant Starch

The resistant starch (RS) content was determined following AOAC (2000). In brief, 100 mg of sample was pre-washed twice with 8 mL of 80% ethanol (v/v) and centrifuged at 4000 \times g for 15 minutes. The residue was then treated with 4 mL of tris-maleate/0.1 M NaOH buffer (pH 6) containing 0.02% sodium azide, amyloglucosidase (4 U/mL, Sigma Aldrich® A 7255), α -amylase (300 U/mL, Sigma Aldrich® A-3176), and pepsin (500 U/mL, Sigma Aldrich® P-7012).

The tubes were shaken, covered, and incubated at 37 °C for 16 hours with continuous stirring. Post-incubation, 8 mL of 99% ethanol was added, and the tubes were shaken and centrifuged at 4000 \times g for 10 minutes. The ethanol rinse was repeated, and the resulting pellets were collected.

To suspend the pellet, 3 mL of 2 M KOH was added, and the mixture was stirred using a magnetic stirrer (REMI 2MLH) for 20 minutes. Next, 10 mL of sodium acetate buffer–glacial acetic acid (1.2 M, pH 3.8) was added, and the stirring was stopped. Subsequently, 0.1 mL of amyloglucosidase (3200 U/mL in sodium acetate buffer, pH 4.75) was added, and the mixture was incubated in a water bath at 50 °C for 30 minutes under constant agitation.

After incubation, the mixture was diluted to 20 mL with distilled water and centrifuged at 4000 \times g for 10 minutes. The resistant starch content was quantified using the Glucose Oxidase/Peroxidase (GOPOD) kit (Sigma Aldrich® GAGO-20), with D-glucose as the reference standard. The RS content was expressed as g/100 g dry weight of GBF.

Determination of amylose and amylopectin (Sadasivam and Manickam, 2008)

Amylose content was determined using a colorimetric method based on the adsorption of iodine within the helical coils of amylose, forming a blue-colored complex. To perform the analysis, 100 mg of the powdered sample was weighed and mixed with 1 mL ethanol and 10 mL of 1 N NaOH, then heated in a boiling water bath for 10 minutes. The volume was made up to 100 mL. To 2.5 mL of the extract, 20 mL of distilled water was added. Three drops of phenolphthalein indicator was added and the solution was neutralized by adding 0.1 N HCl drop by drop until the pink color disappeared. Subsequently, 1 mL of iodine reagent was added, and the volume was adjusted to 50 mL. The absorbance of the resulting solution was measured at 590 nm. A standard curve was prepared using varying concentrations (0.2, 0.4, 0.6, 0.8, and 1 mL) of the amylose standard solution, following the same procedure as for the sample. A blank was prepared by diluting 1 mL of iodine reagent to 50 mL with distilled water.

The amylose content was calculated using the standard graph, with the absorbance of 2.5 mL of the test solution corresponding to a specific amount of amylose. The percentage of amylose was determined using the formula:

$$\text{Amylose (\%)} = \frac{x}{2.5} \times 100$$

The amylopectin content was calculated by subtracting the amylose content from the total starch content.

Appendix V**Estimation of Physico-Chemical Parameters and Nutrient Composition****Determination of Moisture Content- Hot Air Oven Method AOAC, 2005**

A flat-bottom metallic dish was prepared by spreading a thin layer of finely divided asbestos, which had been pre-dried in a hot air oven at 110 °C for one hour. The dish was then removed from the oven, cooled in a desiccator, and weighed.

A 20 g sample was spread evenly over the asbestos layer in the dish. The sample was dried in the hot air oven at 100 °C for 3–5 hours at atmospheric pressure, without a lid on the dish. After the drying period, the lid was replaced, and the dish was reweighed.

The percentage of moisture content was calculated using the formula:

$$\% \text{Moisture (wt/wt)} = \frac{\text{Weight of wet sample} - \text{Weight of dry sample}}{\text{Weight of wet sample}} \times 100$$

Determination of Ash Content AOAC, 2005

The tare weight of three silica dishes (7–8 cm in diameter) was recorded. Approximately 5–10 g of the sample was weighed into each dish. The dishes and their contents were ignited over a Bunsen burner to begin the ashing process. Subsequently, the material was ashed at a temperature not exceeding 525 °C for 4–6 hours in a muffle furnace. After ashing, the dishes were cooled in a desiccator and reweighed. The total ash content was calculated as the difference in weights before and after ashing and expressed as a percentage of the sample's initial weight.

$$\% \text{Ash Content} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

Determination of pH , Titratable Acidity and TSS AOAC, 2005

Sample preparation

An 8% suspension of unripe banana flour (UBF) was prepared and stirred for approximately 5-7 minutes. The suspension was then allowed to stand for 30 minutes and filtered.

Titrate acidity and pH were assessed using methods 942.15 and 981.12, respectively. Total Soluble Solids (TSS) were estimated using a hand-held Atago Refractometer (Salvador et al., 2007).

The pH of the filtrate was measured using a pH meter. The pH of the sample, indicating its acidity or alkalinity, was determined using a calibrated pH meter, providing a direct measurement of hydrogen ion concentration. Calibration was performed using standard buffer solutions of pH 7.00 and pH 4.00. The pH electrode was rinsed with distilled water, immersed in the pH 7.00 buffer, and adjusted to read 7.00, followed by calibration with the pH 4.00 buffer. After rinsing, the calibration was verified with both buffers. The pH electrode was rinsed, immersed in the sample, and the pH reading was recorded after stabilization.

Titrate acidity represents the total acidity of a sample and is expressed as a percentage of the predominant acid. It was determined by titrating the sample with a standardized sodium hydroxide (NaOH) solution to a defined endpoint, indicated by a color change. A 0.1 N NaOH solution was prepared by dissolving 4 g of sodium hydroxide in distilled water and diluting to 1 liter. A 1% phenolphthalein indicator solution in ethanol was used to indicate the titration endpoint. To the filtrate, 2–3 drops of phenolphthalein indicator were added. The sample was titrated with the standardized 0.1 N NaOH solution until a faint pink color persisted for at least 30 seconds, marking the endpoint. The volume of NaOH used was recorded, and the titrate acidity was calculated using the formula:

$$\text{Titrate Acidity (\%)} = \frac{\text{Volume of NaOH (mL)} \times \text{Normality of NaOH} \times \text{Equivalent Weight of Acid} \times 100}{\text{Weight of Sample (g)}}$$

Determination of Protein AOAC, 2005

The Kjeldahl method was used to determine the nitrogen content in the sample, which was converted to protein using a standard conversion factor of 6.25. The analysis involved digestion, neutralization, distillation, and titration. Approximately 0.5–1 g of the sample was weighed into a Kjeldahl digestion flask, followed by the addition of 10–15 mL of concentrated sulfuric acid (H₂SO₄) and 0.5 g of a catalyst mix containing potassium sulfate and copper sulfate. The flask was heated gently and then boiled until the solution turned clear or light green, indicating complete digestion, which typically required 1–2 hours.

After cooling, the digest was diluted with distilled water and transferred to a distillation unit. A 40% sodium hydroxide (NaOH) solution was added to neutralize the acidic digest, liberating ammonia gas (NH₃), which was distilled into a flask containing 25 mL of 4% boric acid solution and a mixed indicator. The trapped ammonia was then titrated with 0.1 N hydrochloric acid (HCl) until the endpoint was indicated in the auto-titration unit. The nitrogen content was calculated based on the

volume of acid used during titration, and the protein content was derived using the conversion factor 6.25.

Determination of Fat AOAC, 2005

A pre-dried thimble was weighed. A vacuum oven-dried sample was placed into the thimble and reweighed. A pre-dried extraction beaker was also weighed. The extraction thimble was inserted into a glass holding tube and positioned into the apparatus condenser. Petroleum ether was added to the extraction beaker, which was then placed on the apparatus heater. The sample was extracted for 4 hours. The heater was lowered, allowing the sample to cool. The extraction beaker was removed, left to air dry overnight, and then dried at 100°C for 30 minutes. The beaker was cooled in a desiccator and reweighed.

Weight of fat in sample = (beaker + fat) – beaker

% Fat on dry weight basis = (g of fat in sample)/(g of dried sample) X 100

Determination of Total Carbohydrates- Anthrone method (Sadasivam and Manickam, 2008).

Carbohydrates were hydrolyzed into simple sugars using dilute hydrochloric acid. In a hot acidic medium, glucose was dehydrated to hydroxymethyl furfural, which formed a green-colored product with anthrone, exhibiting an absorption maximum at 630 nm. A 100 mg sample was weighed into a boiling tube and hydrolyzed in a boiling water bath for three hours with 5 mL of 2.5 N HCl, then cooled to room temperature. The hydrolyzed solution was neutralized with solid sodium carbonate until effervescence ceased, and the volume was made up to 100 mL before centrifugation. The supernatant was collected, and 0.5 and 1 mL aliquots were taken for analysis. Standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8, and 1 mL of the working standard, with the 0 mL tube serving as the blank. The volume in all tubes, including sample tubes, was made up to 1 mL with distilled water, followed by the addition of 4 mL anthrone reagent. The tubes were heated for eight minutes in a boiling water bath, cooled rapidly, and the green to dark green color was read at 630 nm. A standard graph was plotted with the concentration of the standard on the X-axis and absorbance on the Y-axis, and the amount of carbohydrate in the sample tube was calculated from the graph.

Determination of Total Sugars- Phenol Sulphuric Assay (Sadasivam and Manickam, 2008).

In a hot acidic medium, glucose was dehydrated to hydroxymethyl furfural, forming a green-colored product with phenol, which exhibited an absorption maximum at 490 nm. A 100 mg sample was weighed, and the sugars were extracted twice with 5 mL of hot 80% ethanol. The supernatant was collected and evaporated in a water bath at 80°C. The remaining sugars were dissolved by adding 10 mL of water. Aliquots of 0.1 or 0.2 mL were then pipetted into separate test tubes. Aliquots of the glucose working standard (0.2, 0.4, 0.6, 0.8, and 1.0 mL) and sample solution (0.1 and 0.2 mL) were pipetted into test tubes and adjusted to 1 mL with water, alongside a blank containing 1 mL of water. 1 mL of phenol solution and 5 mL of 96% sulphuric acid, was added to each tube followed by thorough shaking. After 10 minutes, the tubes were shaken again and incubated in a water bath at 25–30°C for 20 minutes. The color intensity was measured at 490 nm, and the total carbohydrate content in the sample solution was calculated using the standard graph.

Determination of Reducing Sugars- Nelson-Somogyi Method

The reducing sugars, when heated with alkaline copper tartrate, reduced copper from the cupric to the cuprous state, resulting in the formation of cuprous oxide. Upon treatment with arsenomolybdic acid, the cuprous oxide facilitated the reduction of molybdic acid to molybdenum blue. The intensity of the blue color developed was compared against a set of standards using a colorimeter at 620 nm.

A 100 mg sample was weighed, and the sugars were extracted twice with 5 mL of hot 80% ethanol. The supernatant was collected and evaporated on a water bath at 80°C. The residue sugars were dissolved in 10 mL of water, and aliquots of 0.1 or 0.2 mL were pipetted into separate test tubes. Aliquots of 0.2, 0.4, 0.6, 0.8, and 1.0 mL of the working glucose standard were pipetted into a series of test tubes, and the volume in both sample and standard tubes was made up to 2 mL with distilled water. A blank containing 2 mL distilled water was prepared separately. To each tube, 1 mL of alkaline copper tartrate reagent was added, and the tubes were placed in boiling water for 10 minutes. After cooling, 1 mL of arsenomolybdic acid reagent was added to each tube, and the volume was made up to 10 mL with water. The absorbance of the blue color was measured at 620 nm after 10 minutes. The amount of reducing sugars in the sample was calculated using a standard graph.

Determination of Dietary Fiber- Sigma Kit TDF-100A

1-gram samples (defatted) of each material were weighed into four tall-form beakers, ensuring sample weights did not differ by more than 20 mg, and weights were recorded to 0.1 mg. To each beaker, 50 mL of pH 6.0 phosphate buffer was added, followed by 0.10 mL of α -amylase (Product Code A3306). The mixtures were covered with aluminum foil and incubated in a boiling water bath, with gentle agitation every 5 minutes. After the internal temperature of the beakers reached 95°C, the samples were incubated for 15 minutes. The solutions were then allowed to cool to room temperature.

The pH of each solution was adjusted to 7.5 ± 0.2 by adding 10 mL of 0.275 N NaOH, and the pH was verified, adjusting further if necessary with NaOH or HCl. A 50 mg/mL solution of protease (Product Code P3910) was prepared in phosphate buffer immediately before use. Then, 0.1 mL (5 mg protease) was pipetted into each beaker. The beakers were again covered with aluminum foil and placed in a 60°C water bath, incubating with continuous agitation for 30 minutes once the internal temperature reached 60°C.

After incubation, the solutions were cooled to room temperature, and the pH was adjusted to between 4.0 and 4.6 by adding 10 mL of 0.325 M HCl to each beaker, with pH adjustments made as needed using NaOH or HCl. Subsequently, 0.1 mL of amyloglucosidase (Product Code A9913) was added to each beaker. Four volumes of 95% ethanol were then added to each beaker, and the solutions were left to stand overnight at room temperature to allow complete precipitation.

For filtration, the beds of Celite in crucibles were wetted and redistributed using 78% ethanol. Gentle suction was applied to draw the Celite onto the frit as an even mat. The precipitate and suspension from each beaker were quantitatively transferred to their respective crucibles under gentle suction. The residues were washed with three 20 mL portions of 78% ethanol, two 10 mL portions of 95% ethanol, and two 10 mL portions of acetone. The crucibles containing the residues were dried overnight in a 105°C air oven or a 70°C vacuum oven. After cooling in a desiccator, the crucibles were weighed to the nearest 0.1 mg, and the weight was recorded as “Residue + Celite + Crucible Weight” (W2). The residues from two samples and two blanks were analyzed for protein using Kjeldahl nitrogen analysis, following AOAC procedures, with a factor of 6.25 used to convert nitrogen to protein unless the nitrogen content was already known. The residues from the remaining

two samples and blanks were ashed in the crucibles at 525°C for 5 hours. After cooling in a desiccator, the weight was recorded as “Ash + Celite + Crucible Weight” (W3).

Residue Weight=W2–W1

Ash Weight=W3–W1

$$\%TDF = \left[\frac{(R_{\text{SAMPLE}} - P_{\text{SAMPLE}} - A_{\text{SAMPLE}})}{SW} \right] \times 100$$

- **TDF** = Total Dietary Fiber
- **R** = Average Residue Weight (mg)
- **P** = Average Protein Weight (mg)
- **A** = Average Ash Weight (mg)
- **SW** = Average Sample Weight (mg)

Determination of Crude Fiber (Sadasivam and Manickam, 2008).

A 5 g defatted sample was weighed and boiled with 200 mL of 0.255 N sulfuric acid for 30 minutes. The acid-digested residue was filtered through a muslin cloth and washed repeatedly with boiling water until it was acid-free. The residue was then subjected to alkali digestion by boiling with 200 mL of 0.313 N sodium hydroxide solution for 30 minutes. Following this, the alkali-digested residue was filtered using a muslin cloth and washed three times with water and ethyl alcohol. The residue was transferred to a pre-weighed crucible, dried in a hot air oven at 130°C for 2 hours, cooled, and weighed.

Determination of Cellulose (Sadasivam and Manickam, 2008).

Cellulose was subjected to acetolysis using an acetic/nitric reagent, forming acetylated cellodextrins that dissolved and hydrolyzed into glucose molecules upon treatment with 67% sulfuric acid. The glucose molecules were dehydrated to hydroxymethyl furfural, which reacted with anthrone to produce a green-colored product. To analyze cellulose, a known amount of the sample (0.5 g or 1 g) was mixed with acetic/nitric reagent, vortexed, and heated in a water bath at 100°C for 30 minutes. After cooling, the mixture was centrifuged, and the supernatant was discarded. The residue was washed with distilled water and treated with 10 mL of 67% sulfuric acid, allowing it to stand for 1 hour. Subsequently, 1 mL of this solution was diluted to 100 mL, and 10 mL of anthrone reagent was added to 1 mL of the diluted solution. The mixture was heated in a boiling water bath for 10 minutes, cooled, and the absorbance was measured at 630 nm using a blank. A standard curve was generated by treating 100 mg of pure cellulose similarly, using various volumes (0.4–2 mL, corresponding to 40–200 µg of cellulose) to develop the color. The amount of cellulose in the sample was calculated by comparing its absorbance to the standard curve.

Determination of Vitamin B6

Vitamin B6 was determined by EN 15652:2009 -HPLC method. Mobile Phase A was prepared by dissolving 0.9611g of 1-Hexane sulfonic acid sodium in 10mL acetic acid, then making up the volume to 1000mL with Type 1 water. Mobile Phase B was methanol (HPLC grade). For sample preparation, 2.0g of the sample was mixed with 25mL HPLC water, degassed in an ultrasonic bath for 30 minutes, and centrifuged at 3000 rpm for 15 minutes. The supernatant was filtered through a 0.45 micron filter and injected into the HPLC system, with a blank injection of Mobile Phase A.

A standard stock solution was prepared by dissolving 0.1000g of Vitamin B6 in 100mL Type 1 water (1000ppm). Working standard solutions (10ppm, 50ppm, and 100ppm) were made by diluting the stock solution with Mobile Phase A.

The HPLC conditions included a C18 column, flow rate of 0.9 mL/min, UV detection at 360nm, column temperature at 40°C ±1°C, and 20µL injections. The run time was 20 minutes, with a gradient elution using Mobile Phase A.

The blank, standard, and sample injections were carried out in the specified sequence, with six replicate injections of the standard solution to ensure precision. The percentage relative standard deviation (RSD) for the area of the standards was calculated, and the RSD should not exceed 5%. Additionally, a bracketing standard solution was injected after every 10 sample injections to maintain consistency and validate the system. The cumulative bracketing standard RSD should also be under 5%.

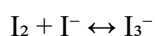
Finally, the analyte concentration in the sample was calculated using the formula:

$$\text{Conc. (mg/L)} = \frac{\text{Working std. soln. Conc. (mg/L)} \times \text{Analyte peak area} \times \text{Dilution} \times \text{Purity of the std}}{\text{Working std. soln. peak area} \times 100}$$

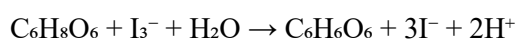
Determination of Vitamin C (Silva *et al.*, 1999)

A 100 g sample was blended with approximately 50 mL of distilled water and strained to separate the liquid portion. The residue on the filter was washed with a small volume of distilled water to ensure a complete transfer of soluble components. The filtrate was then made to a final volume of 100 mL in a volumetric flask with distilled water.

One method to quantify vitamin C in food involves redox titration, which offers higher specificity than acid-base titration due to the presence of other acids in juices that do not interfere with the oxidation of ascorbic acid by iodine. Since iodine is relatively insoluble, its solubility is enhanced by forming triiodide through complexation with iodide:



The triiodide then oxidizes vitamin C, converting it into dehydroascorbic acid as follows:



As long as vitamin C is present in the solution, triiodide rapidly converts to iodide ions. When all the vitamin C is oxidized, iodine and triiodide accumulate and react with starch to form a blue-black complex. The appearance of this color marks the titration endpoint.

25 mL of vitamin C standard solution (1mg/ml) was taken in a Erlenmeyer flask and 10 drops of 1% starch solution was added. The burette was rinsed with a small volume of iodine solution and filled, with the initial volume recorded. The sample was titrated with iodine solution until the endpoint was reached, indicated by the appearance of a persistent blue color lasting more than 20 seconds upon swirling. The final volume of the iodine solution was recorded, and the volume required was calculated as the difference between the initial and final readings. Each titration was repeated until at least three consistent measurements, agreeing within 0.1 mL, were obtained. The titration was repeated with 25 ml of PUBF and MUBF extracts. The amount of titrant required for the standard was

determined. If an average of 10 mL of iodine solution was needed to react with 0.250 grams of vitamin C, the vitamin C content in the sample was calculated accordingly.

Determination of calcium (Ranganna, 1997)

Calcium content in the sample was estimated by precipitating calcium as calcium oxalate, dissolving the precipitate in dilute sulfuric acid, and titrating with standardized potassium permanganate (KMnO₄) solution. The procedure involved pipetting 2 mL of the mineral solution into two centrifuge tubes, followed by the addition of methyl red indicator. Ammonia was added until the solution turned light yellow, indicating alkalinity, and acetic acid was added to achieve a salmon pink color, suitable for calcium precipitation.

Ammonium oxalate solution (1 mL) was added, and the tubes were left overnight for complete precipitation. The following day, the tubes were centrifuged at 2000 rpm, and the supernatant was discarded. The precipitate was washed by adding 4 mL of ammonia, followed by repeated centrifugation. After washing, 2 mL of sulfuric acid was added to dissolve the precipitate, and the tubes were heated in a water bath. The hot solution was titrated with standardized 0.01N potassium permanganate. The endpoint was a persistent pink color lasting at least one minute.

Calcium content was calculated using the formula:

$$\text{Calcium (mg/100g)} = \frac{\text{Titre} \times \text{Normality of KMnO}_4 \times \text{Total Volume of Ash Solution} \times 100}{\text{Volume of Ash Solution Taken for Estimation} \times \text{Weight of Sample for Ashing}}$$

Determination of phosphorus (Ranganna, 1997)

Phosphate ion (PO₄³⁻) reacted with molybdic acid (H₂MoO₄) to form phosphomolybdate, a complex ion [PMo₁₂O₄₀]³⁻. The phosphomolybdate, upon reduction, formed another complex called molybdenum blue, which was measured colorimetrically. 20 mg of potassium dihydrogen phosphate was dissolved in 100 mL of water, yielding a phosphate standard solution with a 0.2 mg/mL concentration. Nine standard tubes were prepared, each containing 0.5 mL of molybdate solution, 0.2 mL of reducing solution, and *x* mL of phosphate stock solution plus *y* mL of distilled water, where *x* + *y* = 9.3 mL. A blank solution was prepared by mixing 0.5 mL of molybdate solution, 0.2 mL of reducing solution, and 9.3 mL of water. The wavelength of the colorimeter was set to 660 nm, the reading was adjusted to zero with the blank solution and the absorbance was recorded. A graph of absorbance versus phosphate concentration in the standard solutions was plotted to obtain a calibrated curve. The amount of phosphate in the test solution was determined from the standard curve.

$$\text{Phosphorus (mg per 100 g)} = \left(\frac{\text{mg of P in aliquot of ash solution} \times \text{Total volume of ash solution} \times 100}{\text{mL of ash solution taken for estimation} \times \text{Weight of sample taken for ashing}} \right)$$

Determination of iron (Ranganna, 1997)

The iron content in food was determined by converting iron in the food sample to ferric form using an oxidising agent like potassium persulphate. The oxidised product was treated with potassium thiocyanate to form the red ferric thiocyanate, which was measured colorimetrically at 480 nm. The 1.5, 2.0, and 2.5 ml of the standard solution (0.1 mg of ferric iron per ml) were pipetted into test tubes. 0.5 ml of concentrated HSO, 1 ml of potassium persulphate, and 2 ml of potassium thiocyanate were added, and the volume was made up to 15 ml. The colour was measured as early as possible. The

absorbance was plotted against concentration. The concentration of iron in the aliquot of the sample was then read directly from the calibration curve.

Determination of potassium (999.19 AOAC method ICP-OES)

Test portions were dried and then ashed at 450 °C with a gradual temperature increase of about 50 °C/hr. Alternatively, wet ashing was performed by directly adding concentrated nitric acid to the sample, followed by evaporation to dryness. The residue was dissolved in HNO₃, and analytes were determined by ICP-OES. The apparatus used included an ICP-OES, a muffle furnace with a thermostat, and a hot plate. The reagents and chemicals used were concentrated nitric acid, dilute nitric acid (2:98), hydrogen peroxide (30%), reference standards (ICP multi-element standard traceable to NIST), and intermediate standard solutions prepared by diluting 10 mL of the CRM (Certified Reference Material) 1000 ppm standard solution into 100 mL with reagent water, adding 0.5 mL of nitric acid, and making up to 100 mL in a standard flask (1 mL = 0.1 mg).

For sample preparation, 0.5–1.0 g of a well-homogenized sample was accurately weighed into a clean silica dish, dried at 110 °C, and then transferred to a muffle furnace where the temperature was slowly increased to 550 °C. The contents were ashed for about 3 hours until the ash turned white or brownish-red. The sides of the dish were washed down with water, and 7 mL of HNO₃ were added and mixed well. The sample was dried on a hot plate, and the nitric acid treatment was repeated in 1 mL increments until a white/brownish-red, carbon-free ash was obtained. The solution was then made up to 25 mL with 2% HNO₃ reagent water.

For the preparation of the standard curve, a reagent blank and a series of 100 mL standards containing 0.1, 1.0, and 10.0 mg/L of the standard solution were prepared by diluting a suitable volume of the standard solution with dilute nitric acid. The solution was aspirated, the emission spectra were measured, and a standard calibration graph was constructed by plotting intensity versus metal concentration. Results were expressed as mg/100 g.

Calculate the concentration C of the metal in the test sample according to the formula:

$$\text{Mineral content (C)} = \frac{(A - B) \times V}{M} \times 10$$

Where:

- C is the concentration of metal/mineral in the test sample
- A is the concentration in the test solution (mg/L)
- B is the concentration in the blank solution (mg/L)
- V is the volume makeup of the test solution
- M is the weight of the sample for analysis in grams

Appendix VI

Qualitative Analysis of Phytonutrients

(Sorescu *et al.*, 2018, Kancherla *et al.*, 2019, Shaikh & Patil, 2020)

Tests for alkaloids

Dragendorff's test. By adding 1 mL of Dragendorff's reagent to 2 mL of extract, an orange red precipitate was formed, indicating the presence of alkaloids.

Mayer's test. Few drops of Mayer's reagent were added to 1 mL of extract. A yellowish or white precipitate was formed, indicating the presence of alkaloids.

Tests for flavonoids

Alkaline reagent test. Two to three drops of sodium hydroxide were added to 2 mL of extract. Initially, a deep yellow colour appeared but it gradually became colourless by adding few drops of dilute HCL, indicating that flavonoids were present.

Shinod's test. Ten drops of dilute HCL and a piece of magnesium were added to 1 mL of extract, the resulting deep pink colour indicating the presence of flavonoids.

Lead Acetate: To a small quantity of the extract, lead acetate solution was added. The formation of yellow precipitate indicated the presence of flavonoids.

Test for steroids

Liebermann-Burchard's test: The amount of 0.5 g of the extract was dissolved in 10 mL anhydrous chloroform and filtered. The solution was divided into two equal portions for the following tests. The first portion of the solution above was mixed with one ml of acetic anhydride followed by the addition of 1 mL of concentrated sulphuric acid down the side of the test tube to form a layer underneath. The test tube was observed for green colouration as indicative of steroids.

Test for phenolic compounds and tannins

Ferric chloride test. 2mL of 5% neutral ferric chloride solution was added to 1 mL of extract, the dark blue coloring indicated the presence of phenolic compounds and tannins.

Gelatin Test: Two ml of extract was added to 2 ml of a 1% gelatin solution containing NaCl. The formation of a white precipitate indicated the presence of tannins and phenolic components.

Ellagic Acid Test: The plant extract aqueous solution was mixed with 5% glacial acetic acid and 5% sodium nitrite solution. The solution turned muddy, and a Niger brown precipitate was formed, indicating the presence of phenolic compounds.

Braymer's Test: One ml of extract was mixed with 3 ml of distilled water and 3 drops of 10% ferric chloride solution. A blue-green color appeared, indicating the presence of tannins.

10% NaOH Test: A 0.4 ml plant extract was mixed with 4 ml of 10% NaOH and shaken well. The formation of an emulsion indicated the presence of hydrolysable tannins.

Tests for Quinone

To the 2 ml of extract, concentrated H₂SO₄ was added and shaken well for 5 minutes. A red color appeared, indicating the presence of quinone.

Alcoholic KOH Test: One ml of plant extract was mixed with a few ml of alcoholic potassium hydroxide. A red to blue color change indicated the presence of quinones.

Tests for cardiac glycosides

Keller Killiani test. A solution of 0.5 mL containing glacial acetic acid and 2-3 drops of ferric chloride, was mixed with 2 mL of extract. Later, 1 mL of concentrated H₂SO₄, was added along the walls of the test tube. The appearance of deep blue colour at the junction of two liquids indicated the presence of cardiac glycosides.

Baljet Test: Two ml of extract was mixed with a drop of Baljet's reagent. The appearance of a yellow-orange color indicated the presence of glycosides.

Bromine Water Test: The UBF extract was mixed with a few ml of bromine water. The formation of a yellow precipitate indicated the presence of cardiac glycosides.

Tests for glycosides

Borntreger's Test: To 3 ml of the extract, dilute HSO was added. The solution was then boiled and filtered. The filtrate was cooled, and an equal volume of benzene was added. The solution was shaken well, and the organic layer was separated. An equal volume of dilute ammonia solution was added to the organic layer. The ammonia layer turned pink, indicating the presence of glycosides.

Test for Saponins

Foam Test: To 1 ml of the extract, 20 ml of distilled water were added and shaken well in a measuring cylinder for 15 minutes. A 1 cm layer of foam was formed.

Test for coumarins

3 ml of 10 % sodium hydroxide (NaOH) was mixed with 2 ml of crude extract, appearance of yellow color depicts the presence of coumarins

Test for Lignin

Labat Test: The extract was mixed with gallic acid. The appearance of an olive green color indicated the presence of lignin.

Detection of Anthraquinones

Borntreger's Test: Ten ml of 10% ammonia solution was added to a few ml of filtrate and shaken vigorously for 30 seconds. The appearance of a pink, violet, or red-colored solution indicated the presence of anthraquinones.

Detection of Terpenoids

Two ml of chloroform was added to 5 ml of plant extract and evaporated on a water bath. Then, 3 ml of concentrated H₂SO₄ was added and boiled on a water bath. The formation of a grey-colored solution indicated the presence of terpenoids.

Volatile Oil- Fluorescence Test

Ten ml of extract was filtered until saturation and exposed to UV light. Bright pinkish fluorescence indicated the presence of volatile oils.

Quantitative Analysis of Phytonutrients

Determination of Total Phenolic Content (Singleton & Slinkard, 1977)

The total phenolic content of the dry extracts was determined using the Folin-Ciocalteu assay. A one mL sample (1 mg/mL) was mixed with 1 mL of Folin-Ciocalteu's phenol reagent. After 5 minutes, 10 mL of 7% sodium carbonate solution was added, followed by 13 mL of deionized distilled water, and the mixture was thoroughly mixed. The mixture was then kept in the dark for 90 minutes at 23 °C, after which the absorbance was measured at 760 nm. The total phenolic content was calculated by extrapolating from a calibration curve prepared with gallic acid solution. The estimation of phenolic compounds was conducted in triplicate. The TPC was expressed as milligrams of gallic acid equivalents (GAE) per gram of dried sample.

Determination of Tannin Content (Sadasivam and Manickam, 2008)

The tannin content was determined using the Folin-Ciocalteu method. A 0.1 mL sample extract was added to a 10 mL volumetric flask containing 7.5 mL of distilled water, 0.5 mL of Folin-Ciocalteu phenol reagent, and 1 mL of 35% sodium carbonate solution. The volume was adjusted to 10 mL with distilled water. The mixture was shaken well and kept at room temperature for 30 minutes. A set of reference standard solutions of tannic acid (20, 40, 60, 80, and 100 µg/mL) was prepared in the same manner. The absorbance of the test and standard solutions was measured against a blank at 700 nm using a UV-Visible spectrophotometer. The estimation of tannin content was conducted in triplicate. The tannin content was expressed as milligrams of tannic acid equivalents per gram of dried sample.

Determination of Total Flavonoid Content (Allothman *et al.*, 2009.)

The total flavonoid content was measured using the aluminum chloride colorimetric assay. A reaction mixture consisting of 0.1 g of powdered sample and 4 mL of distilled water was prepared in a 10 mL volumetric flask. After 5 minutes, 0.3 mL of 5% sodium nitrite solution was added, followed by 0.3 mL of 10% aluminum chloride solution. After another 5 minutes, 2 mL of 1 M sodium hydroxide solution was added, and the volume was adjusted to 10 mL with distilled water. A set of reference standard solutions of quercetin (20, 40, 60, 80, and 100 µg/mL) was prepared in the same manner. The absorbance of the test and standard solutions was measured against a reagent blank at 510 nm using a UV-Visible spectrophotometer. The total flavonoid content was expressed as milligrams of quercetin equivalents (QE) per gram.

Determination of Phytic acid (Davies and Reid, 1979)

Ten milliliters of 0.5 M HNO₃ was added to 0.5 g of finely PUBF and MUBF samples and stirred on a magnetic stirrer for 3 hours. Two replicates were prepared for each sample. The mixture was then filtered through Whatman No. 1 filter paper to obtain the extract.

From each replicate, two technical replicates of 0.2 mL were taken separately. To each 0.2 mL extract, 0.2 mL of ferric ammonium sulphate working solution was added in a centrifuge tube. The tubes were placed in a boiling water bath for 20 minutes. After cooling, 1 mL of isoamyl alcohol was added, followed by 0.02 mL of ammonium thiocyanate solution (5 g/50 mL) to induce the color reaction. The tubes were then centrifuged at 3000 rpm for 10 minutes. The supernatant was collected and the color was measured at 465 nm. A series of standards were run alongside each analysis. The standard solution was prepared by dissolving 30.54 mg of sodium phytate in 100 mL of 0.5 N nitric acid.

Methods of Antioxidant Analysis

DPPH Free Radical Scavenging Activity Assay- Carciochiet al.(2014)

1 mL of 0.1 mM DPPH in methanol was mixed with different volumes of UBF extract samples diluted with aqueous methanol at different concentrations. The control was prepared by mixing 1 mL

of DPPH solution with methanol. After incubation at room temperature in dark for 30 min, the absorbance was measured at 517 nm using spectrophotometer. Ascorbic acid was used as the standard. The percentage of scavenging activity of each extract on DPPH radical was calculated as %inhibition of DPPH (I%) using the following equation:

$$I\% = \frac{A_o - A_s}{A_o} \times 100$$

where A_o is the absorption of control and A_s is the absorption of the tested extract solution

ABTS Free Radical Scavenging Activity Assay (Re et al.,1999).

The ABTS assay uses ABTS radicals pre-formed by oxidation of ABTS with potassium persulphate. The ABTS●+ stock (aqueous) solution was prepared by reacting 7 mM ABTS with 2.45 mM potassium persulfate in equal quantities and the mixture was allowed to stand in the dark for 12-16 h at room temperature. The working solution of ABTS●+ was prepared by diluting the stock solution in methanol to give an absorbance of 0.70 ± 0.02 at 734 nm. 2.0 mL of ABTS●+ working solution was mixed with 1 mL of sample extracts of different concentrations. The control was prepared by mixing 2.0 mL of ABTS●+ solution with 1 mL of methanol. Ascorbic acid was used as the standard. The mixture was incubated for 10 min keeping in the dark at room temperature and the absorbance was measured at 734 nm using spectrophotometer. The percentage of scavenging activity was calculated as % inhibition (I%) using the following equation:

$$I\% = \frac{A_o - A_s}{A_o} \times 100$$

where A_o is the absorption of control and A_s is the absorption of the tested extract solution

Ferric Reducing Antioxidant Power (FRAP) Assay- Benzie and Strain (1996)

The ferric reducing capacity of the extracts was investigated using the potassium ferricyanide-ferric chloride method . Briefly, 0.2 mL of each extract at different concentrations, 2.5 mL of phosphate buffer (0.2 M, pH 6.6), and 2.5 mL of 1% potassium ferricyanide $K_3Fe(CN)_6$ were mixed and incubated at 50°C for 20 minutes to reduce ferricyanide to ferrocyanide. The reaction was stopped by adding 2.5 mL of 10% (w/v) trichloroacetic acid, followed by centrifugation at 1000 rpm for 10 minutes. Finally, 2.5 mL of the upper layer was mixed with 2.5 mL of distilled water and 0.5 mL of $FeCl_3$ (0.1%), and the absorbance was measured at 700 nm. Results were expressed in mg of ascorbic acid equivalents (AAE) /100 g.

Antimicrobial Activity- Agar well diffusion method (Balouiri et al., 2016).

Mueller Hinton Agar plates were prepared and inoculated with 200 microliters of a 0.5 MacFarland standard of *E. coli* MTCC 452/ *Staphylococcus aureus* (MTCC 096) in 20 ml of media. Wells of 5 mm diameter were created in the agar, and PUBF and MUBF methanolic extracts (250mg/ ml) of different concentrations (20µL,40µL,60µL,80 µL,100 µL) were placed in the well. The plates were incubated at 37°C for 24 hours, after which the zones of inhibition were measured to evaluate the antimicrobial efficacy.

Appendix VII

In vitro digestibility of starch and predicted GI

A method by Goni et al. (1997) was used to measure the rate of starch hydrolysis. A starch sample (50 mg) was transferred into a tube containing 10 mL of HCl-KCl buffer (pH 1.5) and 0.2 mL (20 mg) of pepsin in HCl-KCl buffer. The tubes were then incubated at 40 °C for 1 hour in a shaking water bath.

The incubated solution was made up to 25 mL with Tris-Maleate buffer (pH 6.9), and 5 mL of PPA (α -amylase from Porcine Pancreas) (3.3 IU) in Tris-Maleate buffer (pH 6.9) was added. The samples were then placed in a shaking water bath and incubated at 37 °C for 3 hours. An aliquot of 1 mL was taken at various intervals (0.5, 1.0, 1.5, 2.0, 2.5, and 3 hours) and heated at 100 °C to deactivate the enzyme.

To this aliquot, 3 mL of sodium acetate buffer (0.4 M, pH 4.75) and 60 μ L of AMG (amylglucosidase from *Aspergillus niger*) were added to hydrolyze the residual starch at 60 °C for 45 minutes. After centrifugation (4500g, 15 minutes), the glucose content was measured using a glucose assay kit. The digestible starch was calculated using the equation:

$$\text{Starch hydrolysis (\%)} = \frac{G_t \times 30 \times 0.9}{50 \times 100}$$

where G_t is the glucose content produced at time t (h). A conversion factor of 0.9 was used to convert the molar mass from glucose to the starch monomer unit.

The digestibility curve of starch follows a first-order equation:

$$C_t = C_\infty (1 - e^{-Kt})$$

C_t = quantity of starch hydrolyzed at time t

C_∞ = quantity of starch hydrolyzed at the endpoint of the reaction

k = digestibility rate constant or first-order rate constant, which was calculated by the equation

$$k = (\ln(C_t/C_\infty))/(-t)$$

$$k = \frac{\ln\left(\frac{C_t}{C_\infty}\right)}{-t}$$

Where t time taken for digesting the starch in minutes

$$AUC = C_\infty (t_f - t_0) - \left(\frac{C_\infty}{k}\right) [1 - \exp - k(t_f - t_0)]$$

The area under the curve (AUC) represents the area under the fitted curve, where t_0 and t_f denote the initial and final hydrolysis times, respectively, and t is the duration of the *in vitro* digestibility kinetics (in minutes).

Hydrolysis Index (HI)

The hydrolysis index (HI) was calculated as the ratio of the area under the hydrolysis curve (AUC) for the test sample to the area under the hydrolysis curve for the reference sample (white bread). This can be expressed as:

$$HI = \frac{AUC_{\text{test sample}}}{AUC_{\text{bread}}}$$

The estimated glycemic index (eGI) was calculated using an equation given by Goni et al.

$$eGI = 39.71 + 0.549HI$$

Appendix VIII

Sensory Evaluation Sheet

Please evaluate the following samples based on the attributes listed below. Use the scale provided to indicate your preference.

Hedonic Scale:

- 1 - Dislike Extremely
- 2 - Dislike Very Much
- 3 - Dislike Moderately
- 4 - Dislike Slightly
- 5 - Neither Like nor Dislike
- 6 - Like Slightly
- 7 - Like Moderately
- 8 - Like Very Much
- 9 - Like Extremely

Product Code	Appearance	Taste	Texture	Flavor	Mouth Feel	After Taste	Overall Acceptability

Appendix IX

Physical Characteristics of Cookies

Weight, Diameter, Thickness, Spread ratio Ahmed et al (2018)

The weight of cookies were determined using an electronic balance. The dimensions of the cookies, specifically the thickness (the distance between the top and bottom surfaces) and width (the distance across the cookie), were determined with a Vernier caliper. The spread ratio of the baked cookies was calculated as the ratio of width(diameter) to thickness.

$$\text{Spread Ratio} = \frac{\text{Diameter}}{\text{Thickness}}$$

Bulk density was determined by the method of Ahmed et al (2018). 50 g of cookies sample was put into a 100 ml measuring cylinder. The cylinder was tapped several times on a laboratory bench to a constant volume. The volume of sample was recorded and bulk density was calculated using the following equation

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of the sample}}{\text{Volume of the sample after tapping}}$$

Physical properties of Muffins

Muffin height was measured as the vertical distance from the bottom to the top of the muffin center using vernier calipers. The weight (g) of the muffins was weighed by using a weighing balance. The height (cm) of the muffins was measured by using a ruler on three different sides. The volume of the muffins were measured according to the standard AACC Method 10–05.01:1998. The principle of the method is based on the displacement of rapeseed by the bread. Volume of displaced rapeseed represents the volume of the muffin and was measured using a 1000 mL graduated cylinder. The muffin sample was placed in a measuring cylinder. The measuring cylinder was filled with rapeseed to the maximum line. The volume of the rapeseed after removing the muffin sample was measured. The volume of the muffin was calculated by subtracting the volume of rapeseed from the volume of the measuring cylinder. The specific volume was calculated by dividing the muffin volume by the muffin weight.

The bulk density (g/) of the sample was calculated by dividing the weights (g) of the sample by the volume (g/). (AACC 2000 Method).

Cooking properties of Noodles and Pasta

Cooking time:

Noodles/ Pasta (10 g) were cooked in 200 ml of boiling distilled water in a 250 ml beaker. Noodles were cooked until the disappearance of the white core, as judged by squeezing between two glass slides (Yadav et al., 2014).

Cooked weight:

The cooked weight of noodles/ Pasta was determined as described by Galvez and Resurreccion (1992) with minor modifications. Noodles/ Pasta (10 g) were soaked in 300 ml water for 5 min and then cooked in a water bath for 5 min. The beaker was covered with aluminum foil to minimize loss of water due to evaporation. The cooked noodles were drained for about 2 min, rinsed with distilled water in a Buchner funnel, and cooked weight was determined by weighing wet mass of noodles

Appendix X

Shelf Life - Peroxide value (PV)

Peroxide value was determined using method given by **AOAC (2000)**. For this, 5 g of sample was taken in Peroxide value (PV) the volumetric flask and then 50 ml of chloroform was added in to it. Volumetric flask was placed on shaker for 2–3 h for extraction of fat. Then, the extract was filtered with Whatman no. 1 filter paper.

From filtered extract, 20 ml was taken in the flask and 30 ml of glacial acetic acid was added to it along with 1–2 ml of saturated potassium iodide solution. Then, the flask was left for 30 min. After 30 min, 50 ml of distilled water and 2 ml of 1 percent starch solution was added into the flask. It turned blue/black coloured solution. The solution was titrated against 0.01 N sodium thiosulphate until it turned to colourless solution. PV was calculated using formula as given below-

S = ml of 0.01N Na₂S₂O₃ (Blank corrected used).

N = Normality of Na₂S₂O₃.

$$PV \text{ (meq. / kg)} = \frac{S \times N \times 1000}{\text{Weight of sample}}$$

Shelf Life – Free Fatty acid (Kaur et al., 2023)

Free fatty acids (FFA) were analysed using method given by Tarladgis et al. (1960) outlined by Kaur et al 2023. Five grams of sample was weighed and added to the flask containing 50 ml of benzene and kept for 30 min. After 30 min, the extract was filtered with the Whatman No. 1 filter paper.

Then, 5 ml from the extract was taken in the flask and 5 ml of benzene, 10 ml of 95 percent ethanol and few drops of phenolphthalein indicator was added in the flask. The solution was titrated against 0.1 N sodium hydroxide till light pink colour appeared. FFA was calculated using formula as given below.

$$FFA\% \text{ as oleic} = \frac{V \times N \times 28.2}{W}$$

Where % FFA= percent free fatty acid (g/100g) expressed as oleic acid

V= Volume of NaOH titrant (ml)

N= Normality of NaOH titrant(mol/1000ml)

282= MW of oleic acid (g/mol) Cruncher = (MW x 100)/1000

W = Sample mass (g)

**Total plate count - - Horizontal method for the enumeration of microorganisms -- Part 1:
Colony count at 30 °C by the pour plate technique- FSSAI Manual 2016**

Medium: The medium includes plate count agar and 0.1% peptone water. For detailed composition

Procedure:

To prepare the food homogenate, a 1:10 dilution of the well-mixed sample is made by aseptically transferring it to the desired volume of diluent. Non-viscous liquid samples, such as milk, should be measured volumetrically and mixed thoroughly with the appropriate volume of diluent, for example, 11 mL into 99 mL, 10 mL into 90 mL, or 50 mL into 450 mL. For viscous liquid samples, weigh the sample and mix it thoroughly with the diluent, such as 11 + 0.1 g into 99 mL, 10 + 0.1 g into 90 mL, or 50 + 0.1 g into 450 mL. Solid or semi-solid samples are weighed and placed into a sterile blender jar or stomacher bag, followed by the addition of 450 mL of diluent. These are blended for 2 minutes at low speed (approximately 8000 rpm) or mixed in a stomacher for 30–60 seconds. Powdered samples can be weighed and directly mixed with the diluent, shaking vigorously (50 times through a 30 cm arc).

In cases where particulate matter floats in the dilution water, the particles should be allowed to settle for 2–3 minutes. The diluent should then be drawn from a portion with minimal food particles before proceeding.

When the expected microbial count exceeds 2.5×10^3 per mL or gram, decimal dilutions are prepared. Each dilution should be shaken 25 times through a 30 cm arc. Fresh sterile pipettes or auto-pipettes should be used for each dilution. To create the dilution, pipette 1 mL of the food homogenate into a tube containing 9 mL of diluent, and transfer 1 mL from this tube to a second tube containing 9 mL of diluent. This process is repeated for further dilutions as needed, with a cyclomixer also being an option for mixing.

For pour plating, Petri plates are labeled with sample number, dilution, date, and other relevant information. One milliliter of the food homogenate and selected dilutions are pipetted into duplicate Petri dishes. Molten PCA (cooled to 42–45°C) is then poured (10–12 mL per dish) within 15 minutes of preparing the original dilution. The media and dilution are gently mixed by swirling clockwise, anti-clockwise, and to-and-fro three times, ensuring the contents do not touch the lid. The plates are allowed to set.

Incubation:

The prepared Petri dishes are incubated in an inverted position at $35^\circ\text{C} \pm 2^\circ\text{C}$ for 48 hours, or at a temperature specified by food regulations, such as for packaged drinking water.

Counting Colonies:

After incubation, colonies are counted on plates containing 30–300 colonies, and the results are recorded per dilution counted.

To calculate the microbial count with a rounded result, the formula is:

$$N = \frac{\sum C}{V \cdot 1.1 \cdot d}$$

Where:

- $\sum C$ is the total number of colonies counted on all the retained dishes.
- V is the volume of inoculum in each dish (in milliliters).
- d is the dilution corresponding to the first dilution retained (for undiluted liquid products, $d = 1$).

Example Calculation:

At the first dilution retained (10^{-2}): 168 colonies.

At the second dilution retained (10^{-3}): 14 colonies.

$$N = \frac{168 + 14}{1 \cdot 1.1 \cdot 10^{-2}} = \frac{182}{0.011} = 16545 \text{ CFU/g or CFU/mL.}$$

Rounding the result to the first two significant digits gives **17000** or **1.7×10^4 CFU/g or CFU/mL**.

Appendix XI

Purchase Intent Form

Dear Participant,

As part of my PhD research *Acceptability of Unripe Banana Flour-based Ready-to-Eat (RTE) and Ready-to-Cook (RTC) Products*, I have developed cookies and noodles using unripe banana flour.

Your feedback is valuable in understanding the potential acceptance of these products in the market. Please indicate your likelihood of purchasing these products by selecting the option that best reflects your preference. Your responses will remain confidential and will only be used for research purposes.

By completing this form, you are providing your consent to participate in this study. Thank you for your time and support.

Sincerely,

A.Haripriya

Research Scholar,

Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.

1. Name _____
2. Area of residence _____
3. Age: 20- 25 years/ 26-40 years/ 41-50 years
4. Gender: Male/ Female
5. Occupation _____
6. Educational Qualification
 - Higher Secondary
 - Graduation
 - Post-Graduation / Higher
7. Household Income per month
 - Below 30000
 - Rs 30000- Rs 50000
 - Rs 50000- Rs 100000
 - Above Rs 100000

Purchase Intent Scale

Please indicate your purchase intent for each product by selecting one option for the following scale:

Point Scale	Description
1	Definitely would not purchase
2	Probably would not purchase
3	May or may not purchase
4	Probably would purchase
5	Definitely would purchase

Product Assessment- What is your likelihood of purchasing these products?

Points Scale/ Products	1	2	3	4	5
Cookies 1 A					
Cookies 1 B					
Noodles 1 A					
Noodles 1 B					



Avinashilingam Institute for Home Science and Higher Education for Women
(Deemed to be University Estd. u/s 3 of UGC Act 1956, Category 'A' by MHRD
Re-accredited with A++ Grade by NAAC. CGPA 3.65/4, Category I by UGC
Coimbatore - 641 043, Tamil Nadu, India

Appendix L2
(Item No 5 of Check List)
Details of Research Publications

S. No	Article	Journal	Other Details Vol/No/Page No/ Year	Published in UGC CARE / Scopus Indexed/ Web of Science
1	Comparative analysis of nutrient and phytonutrient composition of unripe banana flour from <i>Musa paradisiaca</i> L.cv. 'Peyan' and 'Monthan'	Journal of Postharvest Technology	11(3) 2023:125-137 www.jpht.in	UGC CARE I
2	Starch characteristics of unripe banana flour	Journal of Postharvest Technology	www.jpht.in Accepted for publication	UGC CARE I

*Proof of list of Journals from Internet to be attached along with copies of reprints.

Scholar : A.Haripriya (18PHFDP005)

Supervisor : Dr. S. Uma Mageshwari

Checked By:

HoD/Dean of Respective School

The scholar has already published one article in the Journal of Postharvest Technology and is awaiting another publication in the upcoming issues.

Haripriya
19/09/24

The scholar Mrs. Haripriya, A(18PHFDP005) has published/got acceptance from the following journal:

1. Journal of Postharvest Technology - indexed in UGC Care Group I from June 2019 to present.

This may be considered.

J. J. J. J.
19.09.24.
Asst. Librarian.



RESEARCH ARTICLE

Comparative analysis of nutrient and phytonutrient composition of unripe banana flour from *Musa paradisiaca* L. cv. 'Peyan' and 'Monthan'

Haripriya, A.*, Uma Mageshwari, S.

Department of Food Service Management and Dietetics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, India

Received: 04.04.2023

Accepted: 13.07.2023

ABSTRACT

Bananas and plantains are globally significant food crops, cultivated in over 130 countries. The structural, functional, and nutritional compositions of various banana cultivars exhibit considerable diversity and uniqueness. This study aimed to investigate the physical characteristics, nutrient content, phytonutrients, and antioxidant potential of two specific banana cultivars: Peyan (ABB) and Monthan (ABB). The selected bananas were in stage 1 of ripening, characterized by low total soluble solids (1.13-1.2°Brix). The flour yield was 30.17% for Peyan and 23.25% for Monthan. The Monthan variety exhibited higher protein content compared to Peyan. Total carbohydrate content, starch, dietary fiber, and other non-starch polysaccharides were similar in both cultivars. Monthan showed considerably higher levels of flavonoids, while Peyan exhibited higher polyphenolic and tannin content. In the DPHH assay, the methanolic extracts of Peyan and Monthan recorded IC₅₀ values of 5.006 mg/mL and 6.641 mg/mL, respectively. Unripe banana flours, with their high fiber content (13%), rich phytochemical profile, and antioxidant potential, are highly recommended for the development of functional foods.

Keywords: Antioxidant potential, nutrient composition, phytonutrients, unripe banana flour.

Citation: Haripriya, A. and Mageshwari, U.S. 2023. Comparative analysis of nutrient and phytonutrient composition of unripe banana flour from *Musa paradisiaca* L. cv. 'Peyan' and 'Monthan'. *Journal of Postharvest Technology*, 11 (3): 125-137.

INTRODUCTION

India boasts a rich diversity of banana cultivars cultivated in various regions throughout the country, each catering to distinct purposes such as dessert and cooking. Regrettably, approximately one fifth of harvested bananas are rejected in both the wholesale market and post-harvest stages. To address this issue, the manufacturing of unripe banana flour and its derivative products has emerged as a sustainable solution that benefits farmers while offering cost-effective opportunities for the food processing sector (Ravi and Mustafa, 2013). Given the escalating prevalence of obesity, diabetes, and cardiovascular diseases, unripe banana flour presents a promising resource for the development of healthy functional products (Wang et al., 2012).

* For correspondence: A. Haripriya (Email: haripriyaqunalan@gmail.com)

Furthermore, plantain varieties, which occupy around 30% of the cultivated area, are currently underutilized in terms of their nutritional potential (Ravi and Mustafa, 2013). *Musa acuminata* and *Musa balbisiana* are the primary species responsible for the vast majority of parthenocarpic edible bananas. The haploid genome of *Musa acuminata* is referred to as A, while that of *Musa balbisiana* is denoted as B. Typically, dessert varieties consist of triploids and diploids originating from *Musa acuminata*, whereas culinary varieties and plantains are triploids resulting from hybridizations between *Musa acuminata* and *Musa balbisiana* (Hazarika et al., 2014; OECD, 2009).

Peyan (ABB) is a distinctive banana variety cultivated in the regions of Tamil Nadu and Kerala. The fruits of this variety are characterized by their short length, flat sides, and prominent angled ridges. They possess a broad base and a slightly tapered apex, forming a blunt beak. The pedicel, or fruit stalk, is short in length. The skin of the fruit appears green with a subtle bloom and transitions to a dull yellow hue upon full ripening. The peel is thick and leathery, with a spongy fiber on the inner surface. The pulp of the fruit is predominantly white, and the core is easily noticeable. In terms of taste, it offers a unique combination of a mildly sweet and sour flavor, reminiscent of Chikku fruits. Due to its medicinal properties, refreshing cooling effect, and limited availability, Peyan bananas command premium prices in the market. They are particularly recommended for pregnant women, children, and individuals dealing with piles. Synonyms associated with this cultivar include *Mada Vazhai*, *Pey Monthan*, *Pey Valai*, and *Peyan Mayil Vazhai* (Venkataramani, 1946).

Monthan (ABB), a notable commercial banana cultivar in India, is primarily utilized for culinary purposes. However, in the northeastern states, it finds usage in both dessert and cooking applications. The fruits of Monthan measure approximately 10 inches in length and 6 inches in girth. They exhibit a slight curvature, plumpness, and irregular five-sided shape, with prominent angled ridges and flat or slightly inflated sides. The base of the fruit is broad, gradually tapering to a long and angled pedicel, while the apex is broad and features a prominent knob-shaped beak. The skin of the fruit is green, thick, and tough, possessing a significant amount of spongy fiber on the inner surface. When fully ripe, the skin transforms into a straw-yellow color. The pulp of Monthan bananas is firm, cream-colored, with a conspicuous core. The fruit offers a mildly sweet and pasty taste when fully ripe. In several regions of Tamil Nadu and Kerala, Monthan fruits are consumed by individuals suffering from chickenpox due to their perceived cooling effect on the body. Regional synonyms associated with this cultivar include *Bontha*, *Kanch Kela*, *Bankel*, *Bantheesa*, and *Kalyanakai* (Venkataramani, 1946).

This study was conducted with the objective of comprehending the physical characteristics, nutrient composition, secondary metabolites, and antioxidant capacity of unripe banana flour derived from *Musa* cultivars Peyan and Monthan. The valuable insights gained from this investigation have the potential to enhance the effective utilization of unripe banana flour as a functional food. The results of this study are significant for promoting the development and utilization of unripe banana flour within the food industry.

MATERIALS AND METHODS

Procurement and determination of ripening stage

The selected cultivars, Peyan (ABB) and Monthan (ABB), were obtained from the wholesale fruit market in Chennai, Tamil Nadu. The authenticity of the fruits was verified by the Department of Pharmacognosy, Siddha Central Research Institute (Central Council for Research in Siddha, Ministry of AYUSH, GOI), Chennai, with the assigned Form No. PCOG002-ACF. The ripening stages of the fruits were determined using the Von Loesecke (1950) scale, which categorizes the ripening process into seven stages based on the color of the peel. These stages are defined as follows: C1 - completely green; C2 - green with slight traces

of yellow; C3 - predominantly green with more green than yellow; C4 - predominantly yellow with more yellow than green; C5 - yellow with green edges; C6 - fully yellow; and C7 - yellow with brown spots. For this study, bananas at stage 1 of ripening were specifically chosen.

Campuzano et al. (2018) described a method to validate the appropriate ripening stage of the samples by assessing the Total Soluble Solids (TSS). This method was adapted and implemented to reconfirm the ripening stage of the bananas. In summary, 30 g of banana pulp was blended for two minutes in 90 mL of water, and the TSS was measured using a handheld Atago refractometer, which has a scale ranging from 0 to 30 °Brix.

Physical characteristics

The physical characteristics of the unripe green banana fruits were assessed using the methodology outlined by Dadzie and Orchard (1997). Measurements were conducted on 12 fruits selected from the second and third hands within each bunch. Fruit length was measured from the distal end to the outer curve using a measuring tape. Additionally, the circumference of each fruit was measured at its widest midpoint. The weight of the entire fruit, as well as the individual weights of the pulp and peel, were determined using a digital weighing balance.

Preparation of unripe banana flour and its yield

The unripe bananas were carefully washed and peeled by hand using a steel knife. The peeled bananas were then sliced into 1 cm thick pieces. To prevent enzymatic browning, the slices were rinsed in a solution of citric acid (0.3g/100mL). Following this, the slices were dried in a tray drier at a temperature of 50°C until they became brittle. Once dried, the slices were pulverized for 120 seconds, sieved through a 60-mesh sieve, and the resulting powder was collected. The powder was then cooled and stored in HDPE bags at ambient temperature (Kumar et al., 2019). Figure 1 and Figure 2 depict the visual representation of the selected cultivars Peyan and Monthan, respectively. The percentage yield of unripe banana flour (UBF) was calculated using the following formula given: $UBF \text{ yield (\%)} = (\text{Fresh weight of the pulp} - \text{Moisture content of the pulp}) / \text{Fresh weight of the pulp} \times 100$.



Fig 1: *Musa paradisiaca* 'Peyan'

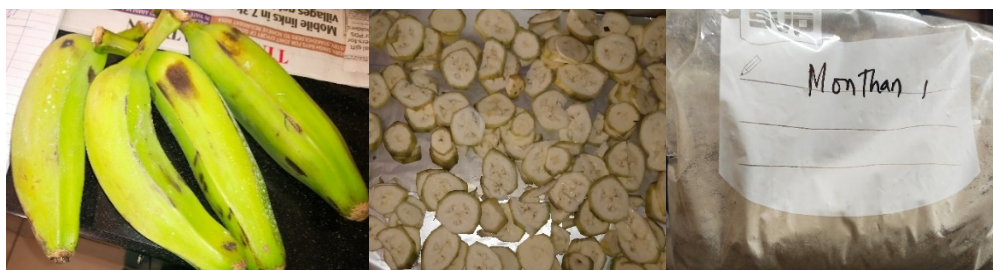


Fig. 2: *Musa paradisiaca* 'Monthan'

Proximate composition

The proximate composition of the unripe banana flours, as well as the pH and titratable acidity, were determined following the methods outlined by AOAC (2005). The moisture content of both the unripe fruit and unripe banana flour was determined using method 925.10. Titratable acidity and pH were assessed using methods 942.15 and 981.12, respectively. An 8% suspension of unripe banana flour (UBF) was prepared and stirred for approximately 5-7 minutes. The suspension was then allowed to stand for 30 minutes, filtered, and the pH of the filtrate was measured (Sundaralingam and Ravindran, 1993). Additionally, using the same slurry, Total Soluble Solids (TSS) were estimated using a refractometer (Salvador et al., 2007).

The total mineral content of the samples was determined by ashing at 525°C for 5-6 hours using a muffle furnace (923.03). Protein estimation was carried out using the Kjeldahl method with the conversion factor $N \times 6.25$ (978.04), while fat was extracted using petroleum ether in Soxhlet apparatus (960.39). Total dietary fiber was estimated using the Sigma TDF 100A kit, following the procedures outlined in the AOAC 15th edition (1990). The cellulose content was determined according to the protocol provided by Sadasivam and Manickam (2008). Crude fiber was quantified using the residue obtained after acid and alkali digestion and pectin content was reported as calcium pectate. Total carbohydrate and starch were determined using the Anthrone method (Sadasivam and Manickam, 2008). Soluble sugars were extracted using 80% hot ethanol (80°C). The supernatants were pooled together, and the ethanol was evaporated. The residues were then reconstituted with water. Total sugars were analyzed using the Phenol-sulfuric acid assay, while reducing sugars were assayed using the Nelson-Somogyi method (Nelson, 1994).

Secondary Metabolites

One gram of unripe banana flour (UBF) was combined with a 25 mL mixture of methanol and water (v/v, 20:5). The resulting mixture was subjected to orbital shaking at 100×g for 8 hours at a temperature of 37°C. Subsequently, it was centrifuged at 4000×g for 10 minutes, and the liquid fraction was gathered for the estimation of secondary metabolites and the DPPH assay (Savlak et al., 2016).

Preliminary qualitative screening for phytochemicals was performed using standard methods (Sorescu et al., 2018). The Folin-Ciocalteu reagent method (Singleton and Slinkard, 1997) was employed to assess the overall phenolic content of UBF. The findings were expressed as milligrams of gallic acid equivalents (GAE) per 100 grams of UBF (based on its dry weight). Total tannins were quantified using the Folin-Denis method with Tannic acid as the standard (Schanderl, 1970). The estimation of flavonoids was conducted using the aluminium chloride colorimetric technique (Allothman et al., 2009) and expressed as milligrams of quercetin equivalents (QE) per 100 g of UBF (dry weight). The method introduced by Davies and Reid (1979) was employed to assess the levels of phytic acid.

Antioxidant potential

The DPPH (1,1-Diphenyl-2-Picrylhydrazyl) Free Radical Scavenging Activity Assay was conducted following the method. The sample extracts were diluted with aqueous methanol to obtain different concentrations. A mixture of 1 mL of 0.1 mM DPPH in methanol and 2 mL of sample extracts was prepared and incubated in the dark for 30 minutes at ambient temperature. The absorbance of the mixture was then measured at 517 nm using a spectrophotometer. A control solution of 1 mL of DPPH solution with methanol was also prepared. The percentage of scavenging activity of each extract on the DPPH radical was calculated as the % inhibition of DPPH (I%) using the following equation: $I\% = [(A_o - A_s) / A_o] \times 100$, where A_o represents the absorption of

the control and As represents the absorption of the tested extract solution. Ascorbic acid was used as the reference standard (Carciochi et al., 2014).

Statistical analysis

The physical characteristics were measured using 12 fruits, and all experimental analyses were conducted in triplicates. The results are presented as Mean ± SD. To determine significant differences between the Peyan and Monthan cultivars, an independent t-test (two-tailed) was performed. Data analysis was conducted using Microsoft Excel 2019.

RESULTS AND DISCUSSION

Fruit Characteristics

Table 1 presents the physical characteristics and flour yield of the selected cultivars. Fruit length and circumference showed variations between the cultivars, with Monthan exhibiting significantly greater values. This trend was also reflected in fruit weight, pulp weight, and peel weight, where Monthan had higher measurements. The pulp/peel ratio for Monthan was determined to be 2.10 ± 0.19 , indicating a relatively higher proportion of pulp compared to the peel. In contrast, Peyan had a thicker peel and a lower pulp/peel ratio of 1.70 ± 0.24 . Previous research studies have reported a pulp/peel ratio of 1.9 for Monthan (Sundaralingam and Ravindran, 1993; Kumar et al., 2019). The selected samples for analysis were in stage 1 of ripening, characterized by a completely green appearance. The moisture content of fresh unripe bananas from Peyan and Monthan cultivars was measured at 69.56 ± 1.48 and 76.80 ± 2.49 , respectively.

Table 1: Physical characteristics and Yield

Fruit Characteristics and Yield	Peyan	Monthan	<i>p</i> * value
Fruit length (cm) [#]	12.16 ±1.01	18.75 ±0.45	.00001
Fruit Circumference (cm) [#]	12.68± 0.62	15.98 ±0.73	.00001
Fruit wt (g) [#]	74.42 ±4.15	192.71±4.81	.00001
Pulp wt (g) [#]	46.75±3.21	130.39±6.53	.00001
Peel wt (g) [#]	27.68 ±2.57	62.31±3.35	.00001
Pulp/ Peel ratio [#]	1.70±0.24	2.10±0.19	.00018
Moisture Content (%) [§]	69.56 ±1.48	76.80 ± 2.49	.00001
Total Solids (%) [§]	30.44 ±1.47	23.20±2.49	.0023
Brix(°Brix) [§]	1.13±0.11	1.2 ±0.2	.6433
Flour Yield (%) [§]	30.17 ±0.40	23.25 ±0.07	.0017

[#] Data presented are mean value of 12 measurements ± standard deviation (n = 12)

[§]Data presented are mean value of triplicates ± standard deviation (n = 3)

*t test (Independent samples, two tailed) p value <0.05 significant

TSS, which represents the soluble solid content, tends to increase as the bananas ripen (Bugaud et al., 2006). In the case of the unripe bananas used in this study at stage 1 of ripening, TSS values of 1.13 ± 0.11 °Brix for Peyan and 1.2 ± 0.2 °Brix for Monthan unripe fresh fruit were obtained. Previous research studies have reported TSS values ranging from 1.0 to 2.1 °Brix for green bananas (Campuzano et al., 2018; Alkarkhi et al., 2011). The lower TSS content in green bananas is expected, as various enzymes are involved in starch breakdown and the formation and accumulation of soluble sugars occur during the ripening process (Emaga et al., 2007).

Flour Yield

The banana flours obtained from both cultivars had a creamy pale-yellow color. The flour yield for Peyan was determined to be $30.17 \pm 0.40\%$, while for Monthan it was $23.25 \pm 0.07\%$. Achieving a higher yield of quality flour is important for obtaining better prices for the finished products. In a previous research study, flour yields of 25.5% and 31.3% were reported for Monthan and Alukehel varieties, respectively (Sundaralingam and Ravindran,1993). The lower flour yield observed in the Monthan variety compared to Peyan can be attributed to its relatively high moisture content (76.81%) and the well-developed vascular tissue present in the fruit. The flours were coded as PUBF (Peyan unripe banana flour) and MUBF (Monthan unripe banana flour), and the results of the proximate analysis are presented in Table 2.

Table 2: Proximate composition of unripe banana flour

Proximate Composition	Peyan	Monthan	p*value
(Per 100g on dry weight basis)	(PUBF)	(MUBF)	
Moisture (%)	3.95 ±0.75	8.67 ±0.67	.000371
Total Solids (%)	96.05± 0.67	91.33 ±0.67	.000371
pH	4.54 ± 0.02	6.4±0.11	.00001
Brix(°Brix)	2.86 ±0.11	1.97±0.05	.00027
Titrateable acidity (as % citric acid)	0.22±0.01	0.43±0.01	.000015
Ash (%)	3.89 ±0.24	4.51±0.187	.006408
Protein (g)	4.89±0.18	6.15±0.52	.007849
Fat (g)	1.96 ±0.07	1.36 ± 0.29	.028044
Total Carbohydrate (g)	88.03 ±1.16	86.70±1.71	.305105
Total Starch (g)	84.76 ± 1.67	82.58 ±1.60	.109106
Total Sugar (g)	2.87 ±0.05	2.94±0.05	.292893
Reducing sugar (g)	1.16±0.02	1.03±0.38	.582414
Dietary Fiber (g)	13.77 ±0.53	13.41 ±0.43	.40901
Crude Fiber (g)	1.17±0.51	1.52±0.28	.360199
Cellulose(g)	2.12±0.05	3.11±0.39	.071022
Pectin as calcium pectate (%)	0.144 ±0.01	0.176 ±0.05	.448023
Data presented are mean value of triplicates ± standard deviation (n = 3)			
*t test (Independent samples, two tailed) p value <0.05 significant			

Proximate Composition

The moisture content of dried food products plays a crucial role in their storage stability. Higher moisture content can negatively impact the textural, chemical, and biochemical properties of the product and promote microbial growth (Traynham et al., 2007).

Typically, a moisture content of around 10% is considered ideal for ensuring good shelf life (FAO, 2004). In this study, the moisture content of unripe banana flours was found to be $3.95 \pm 0.75\%$ for Peyan and $8.67 \pm 0.67\%$ for Monthan. These moisture content values suggest that unripe banana flour has good potential for maintaining its quality and stability during storage. In a different study, the moisture content of plantain flours from hybrid plantain varieties ranged from 6.15% to 7.27% (Anajekwu et al., 2020) Another scientific study reported a moisture content of 6.0% for unripe banana flour (Rodrı́guez-Ambriz et al., 2008).

The pH of the unripe banana flours ranged from 4.54 ± 0.02 (Peyan) to 6.4 ± 0.11 (Monthan). A titratable acidity of 0.22- 0.43 % was obtained. In a similar study, a pH of 5.0 ± 0.10 and 5.78 ± 0.20 was reported for Nendran and Popoulu varieties. Titratable acidity of 0.61 ± 0.03 and 0.85 ± 0.02 g of citric acid/100 g d.w was reported for Saba and Nendran variety (Kumar et al., 2019). Oxo-acids present such as malic, oxalic, and citric contribute to the acidity of the flour (Wyman and Palmer, 1964). The ash content in food is widely recognized as an indicator of the total mineral content, representing the inorganic residue left after organic matter is burned (Ferreira and Tarley, 2020). In the selected cultivars, the ash content ranged from 3.89% to 4.51%. Kumar et al. (2019) reported an ash content of 3.25 g/100g for Monthan and 2.06-2.50 g/100g for other varieties in their research study. Another study reported ash content of $4.2 \pm 0.5\%$ and $3.3 \pm 0.2\%$ (d.w.) for Monthan and Alukehel, respectively (Sundaralingam and Ravindran,1993).

Proteins play a crucial role in various metabolic reactions during the ripening and senescence of fruits (Shi et al., 2014) and the total crude protein content is determined by the balance between protein synthesis and degradation (Toledo et al., 2012). In this study, Peyan fruit showed a protein content of 4.89 ± 0.18 g/100g, while Monthan had a significantly ($p < 0.05$) higher value of 6.15 ± 0.52 g/100g. Another study reported a protein content of 3.69 ± 0.07 g/100g for ripening stage 1 Banana Cavendish of *Musa acuminata* (AAA) (Campuzano et al., 2018). The protein content of unripe banana flour of Awak ABB variety was recorded as 6.77 g/100g (Haslinda et al., 2009). In the case of Monthan variety (ABB), a protein content of 4.89 ± 0.21 g/100g was reported (Kumar et al., 2019). According to da Mota et al. (2000), the difference in protein content is primarily influenced by the inherent characteristics of dessert and plantain bananas. It is worth noting that the protein content of UBF is lower compared to wheat flour (10.99 ± 0.69 g/100 g d.w.) as reported by Traynham et al. (2007). The fat content of Peyan and Monthan was found to be 1.96 ± 0.07 g/100g and 1.36 ± 0.29 g/100g, respectively. Another study reported a lipid content of 0.89 ± 0.04 g/100g for *Musa acuminata* AAA variety (Menezes et al., 2011).

During the pre-climacteric period, the starch content of bananas, which typically ranges from 70% to 80%, reduces to 1% or lower by the conclusion of the climacteric phase, while the sugar content increases to more than 10% of the fruit's fresh weight (Zhang et al., 2005). The total sugar content in green banana flour is generally lower and is significantly influenced by the fruit's maturity stage (Brand-Miller et al., 2009). In the current study, unripe bananas in stage 1 of ripening were found to have a total carbohydrate content ranging from 88.03 g/100g to 86.70 g/100g, with a total starch content ranging from 84% to 82%. The recorded values for total sugars were lower, averaging between 2.87 g/100g and 2.94 g/100g, and reducing sugars ranged from 1.16 g/100g to 1.03 g/100g. The composition of these components in the two varieties showed some similarity. In a previous study, the total sugar content of banana flour was reported to average between 2.9% and 2.7% for the varieties 'Alkuehel' and 'Monthan', respectively (Sundaralingam and Ravindran,1993). Another study by Menezes et al. (2011) reported a relatively modest quantity of soluble sugars (1.81 g/100g) for *Musa acuminata* var. Nanicão.

The selected cultivars exhibited a significant dietary fiber content of 13%. In a study involving the Banana Awak ABB variety, the total dietary fiber content was reported as 7.53%, while unpeeled banana flour had 11.27% (Haslinda et al., 2009). The crude fiber content of Peyan was recorded as 1.17 ± 0.51 g/100g, and for Monthan, it was 1.52 ± 0.28 g/100g. The crude fiber content of Terra (*Musa paradisiaca*) was reported as 1.18 ± 0.07 g/100g (Pelissari et al., 2012). The cellulose content of Peyan was 2.12

± 0.05 g/100g, while for Monthan, it was 3.11 ± 0.39 g/100g. The estimated pectin content, measured as calcium pectate, ranged from 0.144% to 0.176%. In the case of Alukehel, an indigenous Sri Lankan variety, the cellulose content was reported as 3.2 ± 0.7 g/100g, while Monthan recorded 2.9 ± 0.6 g/100g (Sundaralingam and Ravindran, 1993).

Secondary Metabolites

After the qualitative analysis of phytochemicals in this study confirmed the presence of alkaloids, flavonoids, tannins, phenolic compounds, and volatile oils, additional quantitative analysis was conducted and the results are summarized in Table 3. Among these phytonutrients, phenolic compounds stand out as crucial antioxidants found in plants. They serve as primary antioxidants and effectively terminate peroxy radicals (Sulaiman et al., 2011). It is worth mentioning that the composition of bioactive compounds can differ based on several factors, including the banana variety, genomic group, and the prevailing climatic and soil conditions (Anyasi et al., 2015).

Table 3: Phytonutrient composition

Secondary Metabolites (per 100g on d.w)	Peyan (PUBF)	Monthan (MUBF)	p* value
Polyphenols (mg GAE)	118.85 \pm 4.19	87.15 \pm 6.17	.026628
Tannins (mg TAE)	611.62 \pm 5.19	461.32 \pm 7.14	.001719
Phytic acid (g)	0.598 \pm 0.04	0.129 \pm 0.08	.004471
Flavonoids (mg QE)	112.78 \pm 13.47	178.89 \pm 6.73	.001606

Data presented are mean value of triplicates \pm standard deviation (n = 3)

*t test (Independent samples, two tailed) p value <0.05 significant

In the present study, the selected cultivar Peyan exhibited a significantly higher total phenolic content (TPC) of 118.85 \pm 4.19 mg GAE/100g compared to Monthan, which had a TPC of 87.15 \pm 6.17 mg GAE/100g. Tsamo et al. (2014) reported that the pulp of "Pelipita" had the highest TPC (319.5 \pm 70.4 mg GAE/100g FW) among the varieties tested, surpassing "Niangafelo" and "Moto Ebanga". In another study, Monthan exhibited a lower polyphenolic content of 44.50 \pm 0.76 mg GA/100g (Kumar et al., 2019).

Tannins, which are water-soluble polyphenols found in plant foods (Sehrawat et al., 2006), possess functional properties (Mazni et al., 2016). The presence of tannins in bananas contributes to the unpleasant astringent taste, with higher levels typically found in the peels compared to the pulp. The decrease in astringency observed in ripe fruits is more likely attributed to alterations in the structure of tannins rather than a reduction in their overall levels (Hubbard et al., 1990). In this study, the tannin content was measured as 611.62 \pm 5.19 mg TAE/100g for Peyan and 461.32 \pm 7.14 mg TAE/100g for Monthan.

A statistically significant difference was observed in the phytic acid content between the two cultivars, with Monthan exhibiting a lower value. Similar findings were reported for phytic acid content (5.1-7.6 mg/g) in commercial raw banana flour samples (Ferreira and Tarley, 2020). The concentration of phytic acid in *M. sinensis* and *M. paradisiaca* was within the range of 2.26-

2.46% (Oyeyinka and Afolayan, 2019). Phytic acid concentrations in various cereals, vegetables, seeds, and fruits have been reported to range from 0.1 to 17.9 mg/g (Lott et al., 2000). Tannins and phytates have been associated with blood glucose reduction and improved insulin response (Thompson, 1993). Additionally, the concentration of phytic acid, polyphenolic compounds, or tannins in starchy foods is inversely correlated with the in-vitro rate of starch digestion (Yoon et al., 1983).

Flavonoids, which belong to the polyphenol family and possess diphenyl propane skeletons, have been extensively studied for their potential health benefits, including anti-inflammatory, hypolipidemic, hypoglycemic, and antioxidant activities (Vijayakumar et al., 2008). Previous research has identified the presence of flavonoids such as epicatechin and myricetin 3-O-rhamnosyl-glucoside in banana flour derived from cultivars like "Mabonde," "Luvhele," and "M-red" (Anyasi et al., 2015).

In this study, the selected cultivars demonstrated a noteworthy content of flavonoids. Monthan exhibited a significantly higher value (178.89 ± 6.73 mg QE/100g) compared to Peyan (112.78 ± 13.47 mg QE/100g) in terms of flavonoid content, as determined by the analysis.

In vitro antioxidant potential

A lower IC₅₀ value in the DPPH assay indicates a higher ability to scavenge free radicals and disrupt free radical chain reactions (Frankel, 1991). The IC₅₀ values were determined by employing Quest Graph™ IC₅₀ Calculator (AAT Bioquest, 2023) based on a logistic regression model. In this study, the methanolic extracts of Peyan and Monthan recorded IC₅₀ values of 5.006 mg/mL and 6.641 mg/mL, respectively. The reference ascorbic acid standard exhibited an IC₅₀ value of 10.13 µg/mL. Figure 3 illustrates the DPPH free radical scavenging activity of UBFs and Vitamin C.

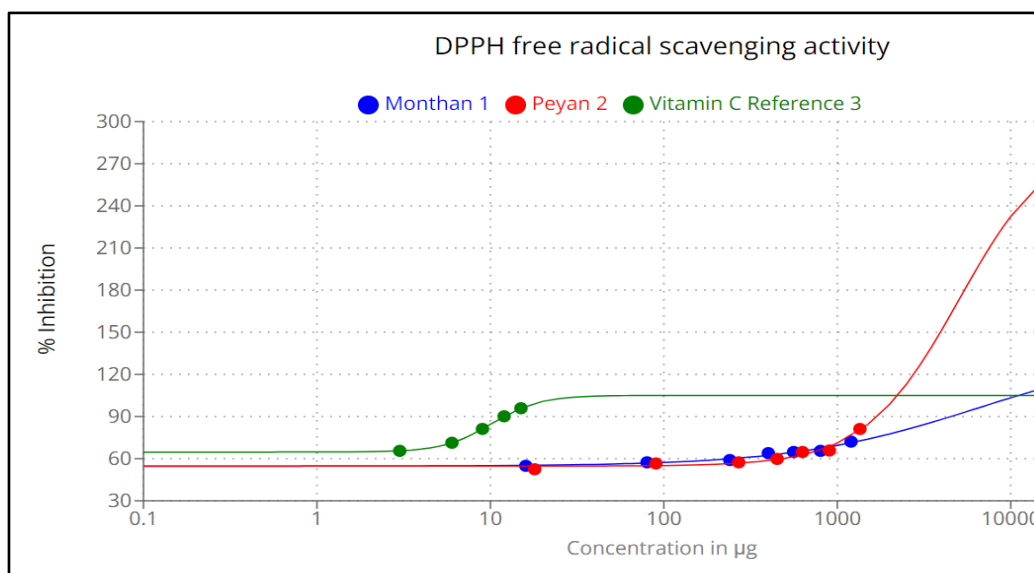


Fig. 3: DPPH free radical scavenging activity of UBFs and Vitamin C

In a study on Musa ABB cv. Klwai namwa, the IC₅₀ values in the DPPH assay were found to be 5.46 mg/mL and 2.54 mg/mL for the ethanolic and methanolic extracts of unripe banana flour (Jannoey et al., 2012). The considerable capacity for scavenging free radicals observed in this study can be ascribed to the advantageous phytonutrient profile of the chosen cultivars.

CONCLUSION

This study presents a thorough examination of the nutrient composition and phytonutrients found in unripe banana flours derived from the Peyan and Monthan cultivars. These flours, rich in dietary fiber and abundant phytonutrients, exhibit a high antioxidant capacity, making them a promising supplement for the development of functional foods. Incorporating banana flour into various convenience and ready-to-eat food products can not only offer consumers healthier choices but also provide a sustainable solution for utilizing excess or rejected bananas. The findings of this study encourage further exploration of the potential of Peyan and Monthan banana flour as a functional ingredient, enabling the development of nutritious and appealing food options.

ACKNOWLEDGEMENT

The authors thank M.O.P Vaishnav College for Women, Chennai-34 for providing research facilities to carry out this work.

REFERENCES

- Ravi, I., and Mustaffa, M.M. 2013. Starch and amylose variability in banana cultivars. *Indian Journal of Plant Physiology*, 18: 83–87. <https://doi.org/10.1007/s40502-013-0014-2>
- Wang, Y., Zhang, M., and Mujumdar, A.S. 2012. Influence of green banana flour substitution for cassava starch on the nutrition, color, texture and sensory quality in two types of snacks. *LWT-Food Science and Technology*, 47(1): 175–182.
- Hazarika, B.N., Sankaran, M., RemaMenon., Sudha. R., Jai Prakash, P., Suresh Kumar, K.N., Shiva, S., Romen Singh., and Rabha, A. 2014. Chapter: 4. Banana. In: *Tropical and Sub tropical Fruit Crops Crop Improvement and Varietal Wealth* (Ghosh S N) Jaya Publishing House, Delhi, p. 66.
- OECD. 2009. Consensus Document on the Biology of Bananas and Plantains (*Musa spp.*) ENV/JM/MONO 43 (<http://www.oecd.org/biotrack>)
- Venkataramani, K.S. 1946. Studies on Indian Bananas. *Proceedings of the Indian Academy of Sciences*, 23: 113– 128. <https://doi.org/10.1007/BF03049665>
- Von Loesecke, H.W. 1950. *Bananas: chemistry, physiology, technology*. Interscience Publishers, No. 634.772/V947.
- Campuzano, A., Rosell, C.M., Cornejo. F. 2018. Physicochemical and nutritional characteristics of banana flour during ripening. *Food Chemistry*, 256: 11-17. <https://doi.org/10.1016/j.foodchem.2018.02.113>
- Dadzie, B.K., and Orchard, J.E. 1997. Routine Post-Harvest Screening of Banana/Plantain Hybrids: Criteria and Methods. INIBAP Technical Guidelines 2, International Plant Genetic Resources Institute, Montpellier, pp. 75-85.
- Kumar, P.S., Saravanan, A., Sheeba, N., Uma, S. 2019. Structural, functional characterization, and physicochemical properties of green banana flour from dessert and plantain bananas (*Musa spp.*). *LWT*, 116:108524. <https://doi.org/10.1016/j.lwt.2019.108524>
- AOAC. 2005. *Official Methods of Analysis*. 18th ed. Association of Official Analytical Chemists, Gaithersburg, MD.


- Sundaralingam., and Ravindran. 1993. Physical and biochemical properties of green banana flour. *Plant Foods for Human Nutrition*, 43: 19-27.
- Salvador, A., Sanz, T., Fiszman, S.M. 2007. Changes in colour and texture and their relationship with eating quality during storage of two different dessert bananas. *Postharvest Biology and Technology*, 43: 319–325.
- AOAC. 1990. *Official Methods of Analysis*. 15th ed. Association of Official Analytical Chemists, Arlington, VA.
- Sadasivam., and Manickam. 2008. *Biochemical Methods*. 3rd ed, New Age International, New Delhi, pp.1-19.
- Nelson, N. 1994. A photometric adaption of the Somogyi method for the determination of glucose. *Journal of Biological Chemistry*, 153: 375–380.
- Savlak, N., Türker, B., Yeşilkanat, N. 2016. Effects of particle size distribution on some physical, chemical, and functional properties of unripe banana flour. *Food Chemistry*, 213: 180-186. <https://doi.org/10.1016/j.foodchem.2016.06.064>
- Sorescu, A.A., Nuta, A., Ion, R.M., and Iancu, L. 2018. Qualitative Analysis of Phytochemicals from Sea Buckthorn and Gooseberry. *InTech*. DOI: 10.5772/intechopen.77365.
- Singleton, V.L., and Slinkard, K. 1977. Total phenol analysis: Automation and comparison with manual methods. *American Journal of Enology and Viticulture*, 28:49-55.
- Schanderl, S.H. 1970. *Method in Food Analysis*. Academic Press, New York, p. 709.
- Allothman, M., Bhat, R., and Karim, A.A. 2009. Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. *Food Chemistry*, 115(3): 785–788.
- Davies, N.T., and Reid, H. 1979. An evaluation of phytate, zinc, copper, iron and manganese content and availability from soyabean textured vegetable protein meat substitutes or meat extruders. *British Journal of Nutrition*, 41:579.
- Carciochi, R., Manrique, G., and Dimitrov, K. 2014. Changes in phenolic composition and antioxidant activity during germination of quinoa seeds (*Chenopodium quinoa* Willd.). *International Food Research Journal*, 21 (2):767-773.
- Bugaud, C., Chillet, M., Beauté, M., and Dubois, C. 2006. Physicochemical analysis of mountain bananas from the French West Indies. *Scientia Horticulturae*, 108(2):167-172. <https://doi.org/10.1016/j.scienta.2006.01.024>
- Emaga, T.H., Andrianaivo, R.H., Wathelet, B., Tchango, J.T., and Paquot, M. 2007. Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Food Chemistry*, 103: 590-600. <https://doi.org/10.1016/j.foodchem.2006.09.006>
- Alkarkhi, A.F., bin Ramli, S., Yong, Y.S., and Easa, A.M. 2011. Comparing physicochemical properties of banana pulp and peel flours prepared from green and ripe fruits. *Food Chemistry*, 129(2): 312–318.
- Traynham, T.L., Myers, D.J., Carriquiry, A.L., and Johnson, L.A. 2007. Evaluation of Water-Holding Capacity for Wheat–Soy Flour Blends. *Journal of the American Oil Chemists' Society*, 84: 151. <https://doi.org/10.1007/s11746-006-1018-0>
- FAO. 2004. *Statistical Yearbook*, Statistics Division, Food and Agriculture Organisation, Rome, Italy.

- Anajekwu, E.O., Maziya-Dixon, B., Akinoso, R., Awoyale, W., Alamu, E.O. 2020. Physicochemical Properties and Total Carotenoid Content of High-Quality Unripe Plantain Flour from Varieties of Hybrid Plantain Cultivars. *Journal of Chemistry*, 2020. <https://doi.org/10.1155/2020/5960346>
- Rodríguez-Ambriz, L., Islas-Hernández, J.J., Agama-Acevedo, E., Tovar, J., Bello-Pérez, L.A. 2008. Characterization of a fibre-rich powder prepared by liquefaction of unripe banana flour. *Food Chemistry*, 107:1515–1521.
- Wyman, H., Palmer, J.K. 1964. Organic Acids in the Ripening Banana Fruit. *Plant Physiology*, 39(4):630-3. doi: 10.1104/pp.39.4.630
- Ferreira, M.P., Tarley, C.R.T. 2020. Assessment of in vitro bioaccessibility of macrominerals and trace elements in green banana flour. *Journal of Food Composition and Analysis*, 92:103586. <https://doi.org/10.1016/j.jfca.2020.103586>
- Shi, Y., Jiang, L., Zhang, L., Kang, R., Yu, Z. 2014. Dynamic changes in proteins during apple (*Malus x domestica*) fruit ripening and storage. *Horticulture Research*, 1: 6. <https://doi.org/10.1038/hortres.2014.6>
- Toledo, T.T., Nogueira, S.B., Cordenunsi, B.R., Gozzo, F.C., Pilau, E.J., Lajolo, F.M., Nascimento, J.R.O. 2012. Proteomic analysis of banana fruit reveals proteins that are differentially accumulated during ripening. *Postharvest Biology and Technology*, 70:51-58. <https://doi.org/10.1016/j.postharvbio.2012.04.005>
- Haslinda, W.H., Cheng, L.H., Chong, L.C., and Aziah, A.A.N. 2009. Chemical composition and physicochemical properties of green banana (*Musa acuminata* × *balbisiana* Colla cv. Awak) flour. *International Journal of Food Sciences and Nutrition*, 60(SUP4): 232- 239. DOI: 10.1080/09637480902915525
- da Mota, R.M., Lajolo, F.M., Cordenunsi, B.R., Ciacco, C. 2000. Composition and Functional Properties of Banana Flour from Different Varieties. *Starch/Starke*, 52(2-3):63-68. [https://doi.org/10.1002/\(SICI\)1521-379X\(200004\)52:2/3<63::AID-STAR63>3.0.CO;2-V](https://doi.org/10.1002/(SICI)1521-379X(200004)52:2/3<63::AID-STAR63>3.0.CO;2-V)
- Menezes, E.W., Tadini, C.C., Tribess, T.B., Zuleta, A., Binaghi, J., Pak, N., Vera, G., Dan, M.C., Bertolini, A.C., Cordenunsi, B.R., Lajolo, F.M. 2011. Chemical Composition and Nutritional Value of Unripe Banana Flour (*Musa acuminata*, var. Nanicão). *Plant Foods for Human Nutrition*, 66: 231–237. <https://doi.org/10.1007/s11130-011-0238-0>
- Zhang, P., Whistler, R. L., BeMiller, J.N., Hamaker, B.R. 2005. Banana starch: Production, physicochemical properties, and digestibility – a review. *Carbohydrate Polymer*, 59: 443– 458. <https://doi.org/10.1016/j.carbpol.2004.10.014>
- Brand-Miller, J.C., Stockmann, K., Atkinson, F., Petocz, P., and Denyer, G. 2009. Glycemic index, postprandial glycemia, and the shape of the curve in healthy subjects: analysis of a database of more than 1000 foods. *The American Journal of Clinical Nutrition*, 89(1): 97-105.
- Pelissari, F. M., Andrade-Mahecha, M. M., Sobral, P. J. D. A., and Menegalli, F. C. 2012. Isolation and characterization of the flour and starch of plantain bananas (*Musa paradisiaca*). *Starch-Stärke*, 64(5): 382-391. <https://doi.org/10.1002/star.201100133>
- Sulaiman, S.F., Yusoff, N.A.M., Eldeen, I.M., Seow, E.M., Sajak, A. A.B., Supriatno, and Ooi, K.L. 2011. Correlation between total phenolic and mineral contents with antioxidant activity of eight Malaysian bananas (*Musa* sp.). *Journal of Food Composition and Analysis*, 24(1): 1–10. doi: 10.1016/j.jfca.2010.04.005

- Anyasi, T.A., Jideani, A.I., Mchau, G.R. 2015. Effect of organic acid pretreatment on some physical, functional and antioxidant properties of flour obtained from three unripe banana cultivars. *Food Chemistry*, 172: 515-22. <https://doi.org/10.1016/j.foodchem.2014.09.120>
- Tsamo, C.V.P., Andre, C.M., Ritter, C., Tomekpe, K., Newilah, G.N., Rogez, H., and Larondelle, Y. 2014. Characterization of *Musa* sp. Fruits and Plantain Banana Ripening Stages According to their Physicochemical Attributes. *Journal of Agricultural and Food Chemistry*, 62(34): 8705–8715. <https://doi.org/10.1021/jf5021939>
- Sehrawat, A., Sharma, S., Sultana, S. 2006. Preventive effect of tannic acid on 2-acetylaminofluorene induced antioxidant level, tumor promotion and hepatotoxicity: a chemopreventive study. *Redox Report*, 11(2):85-95. <https://doi.org/10.1179/135100006X101066>
- Mazni, A.Z., Ho, Y.W., Azizul, I., and Nurdin, A. 2016. Antioxidant, antimicrobial, and cytotoxic potential of condensed tannins from *Leucaena leucocephala* hybrid-Rendang. *Food Science and Human Wellness*, 5: 65-75.
- Hubbard, N.L., Mason Pharr, D., Huber, S.C. 1990. Role of sucrose phosphate synthase in sucrose biosynthesis in ripening bananas and its relationship to the respiratory climacteric. *Plant Physiology*, 94:201-208.
- Oyeyinka, B.O., Afolayan, A.J. 2019. Comparative Evaluation of the Nutritive, Mineral, and Antinutritive Composition of *Musa sinensis* L. (Banana) and *Musa paradisiaca* L. (Plantain) Fruit Compartments. *Plants*, 8(12):598. <https://doi.org/10.3390/plants8120598>
- Lott, J., Ockenden, I., Raboy, V., and Batten, G. 2000. Phytic acid and phosphorus in crop seeds and fruits: A global estimate. *Seed Sci Res*, 10(1): 11-33. <https://doi.org/10.1017/S0960258500000039>
- Thompson, L.U. 1993. Potential health benefits and problems associated with antinutrients in foods. *Food Research International*, 26:131-149.
- Yoon, J.H., Thompson, L.U., and Jenkins, D.J.A. 1983. The effect of phytic acid on in-vitro rate of starch digestibility and blood glucose response. *American Journal of Clinical Nutrition*, 38: 835-42.
- Vijayakumar, S., Presannakumar, G., Vijayalakshmi, N.R. 2008. Antioxidant activity of banana flavonoids. *Fitoterapia*, 79: 279–282. <https://doi.org/10.1016/j.fitote.2008.01.007>
- Frankel, E.N. 1991. Recent advances in lipid oxidation. *Journal of the Science of Food and Agriculture*, 54: 495. <https://doi.org/10.1002/jsfa.2740540402>
- AAT Bioquest, Inc. 2023, April 12. Quest Graph™ IC50 Calculator. AAT Bioquest. <https://www.aatbio.com/tools/ic50-calculator>.
- Jannoey, P., Channei, D., Boonsong, T., Pimsen, S., and Nueangjumnong, N. 2012. Phytochemical Screening and Antioxidant Activity of Unripe Banana Flour, NU. *International Journal of Science*, 18(2): 80-102.



© The Author(s)

This is an  Open Access article licensed under a Creative Commons license: Attribution 4.0 International (CC-BY).

RESEARCH ARTICLE

Starch characteristics of unripe banana flour


Haripriya, A*, Uma Mageshwari, S.

Department of Food Service Management and Dietetics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, India

ARTICLE INFO

Received : 28.08.2024
Accepted : 02.10.2024

© The Author(s)

This is an  Open Access article licensed under a Creative Commons license: Attribution 4.0 International (CC-BY).



ABSTRACT

Unripe banana flour is gaining attention as a valuable ingredient in food applications due to its rich nutritional composition and potential health benefits. This study aimed to investigate the morphology and starch fractions of unripe banana flour (UBF) derived from the Peyan and Monthan cultivars (genome ABB). The UBFs were prepared from stage 1 unripe bananas through tray drying at 55°C. Standard protocols were used to determine the structural features and starch composition of UBFs. Scanning Electron Microscopy analysis revealed distinct characteristics of the starch granules in the Peyan and Monthan varieties. X-Ray Diffraction analysis confirmed the presence of B-type crystallinity, with relative crystallinity indices of 8.91% and 13.06% for Peyan and Monthan, respectively. The starch content of UBFs ranged from 82.94% to 86.47%, with an amylose content of 23% and a significant amount of resistant starch (44%). These findings significantly advance our knowledge of the unexplored indigenous cultivars showcasing their potential as a functional ingredient in value-added healthy food products.

Keywords: Unripe banana flour, starch, resistant starch, thermal properties

Citation: Haripriya, A. and Uma, M.S. 2024. Starch characteristics of unripe banana flour. *Journal of Postharvest Technology*, 12 (4): 37-45.

INTRODUCTION

Bananas, which are part of the *Musa* genus, are highly consumed fruits that are grown in tropical and subtropical areas. In recent years, the global banana trade experienced significant growth, with exports reaching a record volume of around 21 million tonnes in 2019 due to increased supply and demand. However, in the first half of 2022, exports decreased by approximately 1.2 million tonnes to about 19.6 million tonnes. Despite facing challenges on the supply side, importing countries maintained strong demand. Intense competition, quality concerns, and market saturation have negatively impacted producer margins and posed sustainability challenges for the banana industry (FAO, 2022). Utilizing green bananas for flour production presents a sustainable solution that can help reduce post-harvest losses. Banana flour holds great potential as a value-added supplement in the human diet (Ahmed et al., 2020) and researchers have recognized its nutraceutical potential leading to the incorporation of green banana flour into a variety of food products. To successfully commercialize and develop new food products based on unripe banana flour, understanding starch characteristics is essential. The Peyan cultivar, originating from South India, has been recognized for its medicinal properties in the traditional food system of Tamil Nadu. However, there is currently no existing literature

discussing its nutritional or functional properties. This study intends to bridge that knowledge gap by investigating the micro and molecular structure and starch fractions of unripe banana flour obtained from two specific varieties: Peyan, the indigenous variety, in comparison with Monthan, a widely cultivated commercial cultivar. The findings of this study will offer valuable insights into the potential applicability of these banana varieties within the food industry.

MATERIALS AND METHODS

Sourcing and processing of green banana flour

The Peyan (ABB) and Monthan (ABB) cultivars used in this study were obtained from the wholesale fruit market in Chennai, Tamil Nadu. The Department of Pharmacognosy at the Siddha Central Research Institute (Central Council for Research in Siddha, Ministry of AYUSH, GOI) in Chennai verified the authenticity of the fruits (Form No. PCOG002-ACF). Bananas at stage 1 of ripening were selected referring to the Von Loesecke scale (1950) and the ripening stage was validated by assessing the Total Soluble Solids (TSS).

The unripe bananas were washed, hand-peeled using a steel knife, sliced into 1 cm thick pieces, and immersed in citric acid solution (0.3g/100mL) to prevent browning. The slices were dried until brittle (55°C), pulverized for 120 seconds, and sifted through a 60-mesh sieve (Campuzano et al., 2018). The unripe banana flour was creamy yellow in color with a moisture content of $3.95 \pm 0.75\%$ and $8.67 \pm 0.67\%$ for Peyan and Monthan, respectively. The UBF was stored in HDPE bags at room temperature for further analysis.

Structural Properties

SEM analysis

Surface morphology observations of the unripe banana flour (UBF) samples were conducted using a scanning electron microscope (FEI-Quanta FEG 200F). The microscope allowed for a resolution of particle sizes ranging from 5 to 100 μm . The samples were affixed to double-sided tape, coated with a layer of gold plating, and then examined to observe their structural characteristics.

XRD analysis

X-ray diffraction (XRD) patterns were generated using an X-Pert Pro PANalytical instrument equipped with a Cu K α source, operating at a voltage of 45 kV and a current supply of 30 mA. The scanning range was set from 10° to 80° (2 θ) with a step size of 0.0170 [°2 θ .] and a scan step time of 5.7150 S. The relative crystallinity (%) was determined from the diffractograms using OriginPro 2023b Software. Relative crystallinity was calculated using the following equation (Kumar et al., 2021)

$$\text{RC (\%)} = \frac{\text{Crystalline peaks}}{\text{Crystalline peaks} + \text{Amorphous peak}} * 100$$

FT-IR analysis

Fourier-Transform Infrared (FT-IR) spectra were recorded using an FT-IR spectrophotometer (SHIMADZU IRAffinity-1S, Miracle 10 ZnSe Prism Plate) within the range of 600-3600 cm^{-1} . The UBF sample was mixed with potassium bromide (KBr) before testing.

Starch Fractions

The determination of total starch, resistant starch, and digestible starch was carried out using established methods as follows:

Total starch analysis

Goni et al. (1997) method was utilized for the determination of total starch content. In this method, a 50 mg of UBF sample was mixed with 2M KOH and allowed to react at room temperature for 30 minutes. Then, sodium acetate buffer (pH=4.75) and amyloglucosidase were added to the sample, followed by an incubation period of 45 minutes in a shaking water bath maintained at 60°C. The starch present in the sample was converted to glucose, which was then quantified using a GOPOD Kit.

Resistant starch analysis

The determination of resistant starch was conducted according to the method 2002.02 AOAC. The starch in UBF was enzymatically hydrolyzed into glucose using pancreatic α -amylase and amyloglucosidase (AMG) over 16-hours at a temperature of 37°C. To halt the reaction, ethanol was added, and the resistant starch (RS) was obtained as a pellet through centrifugation. The RS pellet was then treated with 2M KOH while vigorously stirring in an ice-water bath. Acetate buffer was added to adjust the pH, and the RS was further hydrolyzed to glucose using AMG. The glucose content was determined using GOPOD kit.

Digestible starch analysis

To determine the digestible starch, the original supernatant from the resistant starch analysis was pooled together and the glucose content was measured using the GOPOD method. To quantify the starch content, the glucose value obtained from each analysis (total starch, resistant starch, and digestible starch) was multiplied by a factor of 0.9.

Amylose and amylopectin

The total amylose content of banana starches was determined following the method of McCready et al. (1950) For the analysis, 100 mg of the sample (dry weight basis) was mixed with 1 mL of distilled ethanol and 10 mL of 1 N NaOH and incubated at room temperature overnight. The resulting solution was diluted with distilled water to achieve a final volume of 100 mL. An aliquot of this solution (2.5 mL) was taken and titrated against 0.1 N HCl, with the addition of 20 mL of distilled water. Following that, one mL of iodine reagent was added, and the resulting solution was diluted to 50 mL. The color intensity was measured at 590 nm using a UV-Visible Spectrophotometer, and the amylose content was extrapolated from an amylose standard curve. A blank solution was prepared using one mL of diluted iodine reagent. The difference between the total starch content and the determined amylose content represents the amylopectin content.

Thermal properties- DSC analysis

The thermal properties of the samples were assessed using a differential scanning calorimeter (NETZSCH DSC 204 F1 PHOENIX). For the analysis, a UBF sample weighing between 2.8 and 3 mg (dry weight basis) was directly placed into an aluminium pan. A small volume of deionized water (7 μ l) was added to the sample, and the pan was then sealed and allowed to reach equilibrium for 1 hour before the measurement. The scanning process involved heating the samples at a rate of 10.0 K/min within a temperature range of 20°C to 200°C. An empty aluminium pan with a pierced lid was used as a reference without a sample. The thermograms of the samples, generated with NETZSCH Proteus software, provided values for various parameters,

including the onset temperature (T_o), peak temperature (T_p), final temperature (T_c), gelatinization temperature range (ΔT), and enthalpy (ΔH).

Statistical Analysis

Structural properties and DSC analysis were performed as single determinants, while all other experimental analyses were conducted in triplicates on dry weight basis. The results are presented as Mean \pm Standard Deviation. To assess significant differences between the Peyan and Monthan cultivars, an independent t-test (two-tailed) was carried out. Data analysis was performed using Microsoft Excel 2019.

RESULTS AND DISCUSSION

Morphological insight using SEM

SEM images provide valuable insights into the characteristics of flour granules, including their size, shape, presence of other compounds, structural integrity, and surface morphology (Kumar et al., 2019). In the present study, SEM images of the UBFs (shown in Fig. 1) revealed distinct characteristics of the starch granules from the Peyan and Monthan varieties. The Peyan flour exhibited a combination of irregularly shaped round, oval, spherical, and occasionally flattened or elongated granules. On the other hand, the Monthan flour predominantly showed elongated, oval-shaped granules with a few spheroid forms. The starch granules appeared intact without any fractures, indicating that the process used to obtain UBF did not cause drastic damage to the granule structure. The microstructure of the flour also exhibited varying degrees of fiber presence, which could probably be the amyloplast membranes. In comparison with similar research, Indonesian Cooking banana cultivars Kapas exhibited elongated shape while Kepokand and Nangka cultivars were spherical (Marta et al., 2019)

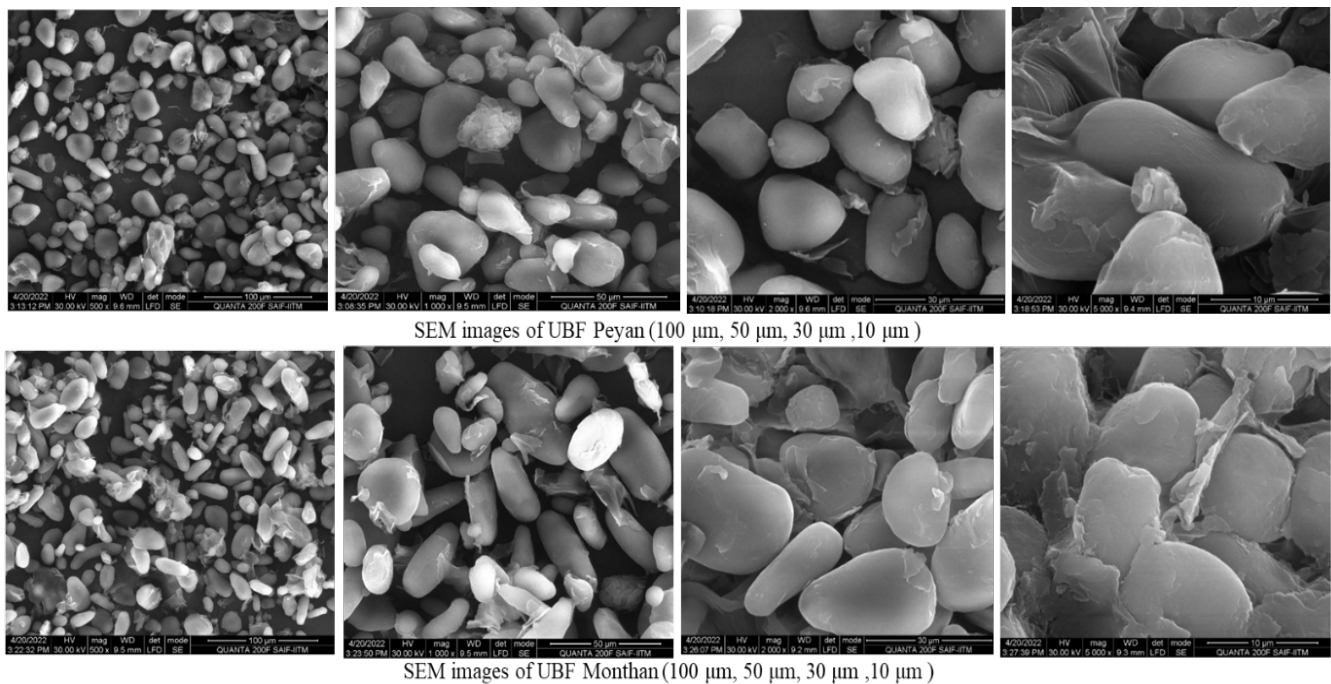


Figure 1: SEM images of UBF Peyan and Monthan

Morphological insight using XRD Patterns

As described by Ouyang et al. (2021) the X-Ray Diffraction (XRD) pattern of type A exhibits pronounced diffraction peaks at approximately 15° and 23°. Additionally, this pattern displays less well-defined peaks around 17° and 18°. In contrast, type B XRD patterns feature the strongest diffraction peaks around 17°, accompanied by smaller peaks at 15°, 20°, 22°, and 24°. Notably, type B patterns also exhibit specific peaks at 5.6°. On the other hand, type C XRD patterns demonstrate a combination of characteristics observed in types A and B.

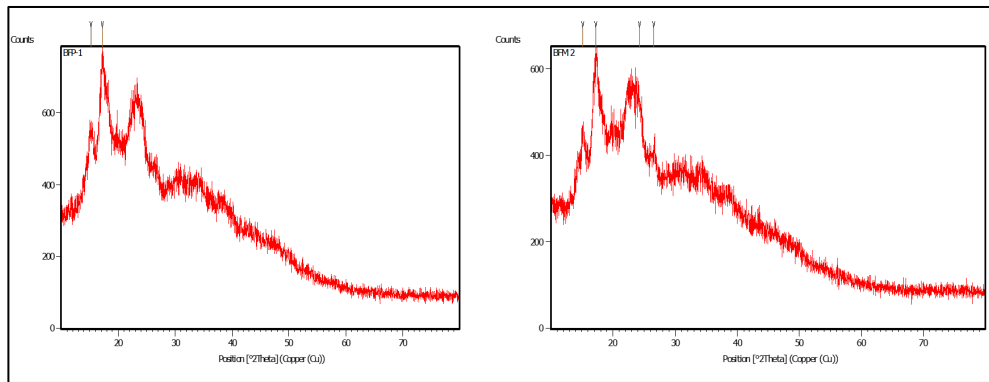


Figure 2. X-ray diffraction patterns- Peyan flour (on right) and Monthan flour

For Peyan flour, the recorded peaks were at 2θ angles of 15.22°, 17.24° and 23.35°. Conversely, Monthan flour exhibited distinctive peaks at 2θ angles of 15.12°, 17.25°, 24.28°, and 26.52°. In our research, we found that the highest peak for both flours appeared at 17.24° - 17.25°, followed by a peak at 15.22° - 15.12°. From the XRD patterns presented in Figure 2, it can be deduced that both Peyan and Monthan flours possess type B crystallinity. Peyan exhibited a relative crystallinity percentage of 8.91%, while Monthan had a relative crystallinity percentage of 13.06%. Starch from unripe banana fruit of Hom Khieo (AAA) and Namwa(ABB) grown in Thailand showed B-type crystalline structure (Thanyapanich et al., 2021). A relative crystallinity of 8.73% was reported for green banana flour in a research work (Padhi et al., 2022).

Morphological insight using FT-IR Spectroscopy

Figure 3 displays the FTIR spectra of the UBFs. The unripe banana flours exhibited a band at 3300 cm⁻¹, indicating the stretching of O-H bonds. The broad band observed around 1334 cm⁻¹ represents O-H bending. The band at 1627-1635 cm⁻¹ signifies C=C stretching. Both cultivars displayed a peak at 1002 cm⁻¹. The results indicate that both cultivars have similar bioactive compounds.

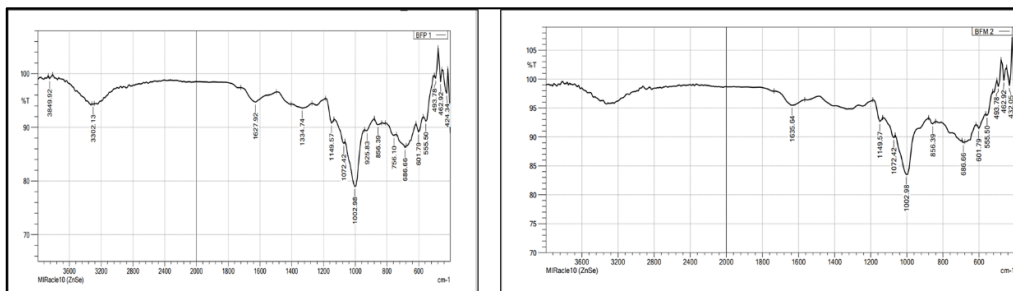


Figure 3: FTIR spectra of Peyan flour (on right) and Monthan flour

Padhi et al. (2022) had reported a peak at 3269 cm^{-1} for UBF, suggesting O-H stretching and indicating the presence of carboxylic acid and alcohol, a peak at 1334 cm^{-1} indicating the presence of phenols and aromatic amines, respectively. The peak at 1002 cm^{-1} can be attributed to the stretching of carbonyl bonds, which are responsible for the characteristic flavor and aroma compounds of bananas (Khoza et al., 2021)

Starch fractions

Starch is the primary carbohydrate component in banana flour and the starch composition of UBFs is depicted in Table 1. The total starch content of Peyan and Monthan UBF was found to be $86.47 \pm 3.05\%$ and $82.94 \pm 3.05\%$, respectively. Starch content ranging from 81% to 93% has been reported for unripe fruits of hybrid plantain cultivars (Anajekwu et al., 2020).

Table 1: Starch composition of Unripe banana flours

Starch Characteristics	Peyan	Monthan	<i>p value</i>
(g/ 100g on dwb)			
Total Starch	86.47±3.05	82.94±3.05	.2302
Amylose	23.34±0.77	23.52±0.64	.731762
Amylopectin	61.49±2.37	59.06±1.35	.134059
Total Digestible starch	43.42±0.37	43.27±0.18	.698489
Resistant Starch	44.75±1.24	44.47±0.87	.822862

Data presented are the mean value \pm standard deviation (n = 3), p value < 0.05 significant independent t-test (two-tailed)

Table 2: Gelatinization characteristics of banana flours

Flour	To °C	Tp °C	Tc °C	ΔT °C	ΔH (J/g)
Peyan	30.44	85.60	162.44	132.0	210.8
Monthan	31.37	88.37	161.37	130.03	253.5

To: onset temperature, Tp : peak temperature, Tc: completion temperature ΔT gelatinization temperature range ($T_c - T_o$), ΔH : gelatinization enthalpy

The composition of amylose and amylopectin in banana flour affects gelatinization, gelation, and retrogradation characteristics. The amylose content plays a vital role in the making up of amorphous region in starch granules and positively associated with resistant starch (RS) content (Cornejo-Ramírez et al., 2018). In the current study, both varieties exhibited an amylose content of 23%, with Peyan having a higher amylopectin content of $61.49 \pm 2.37\text{g}/100\text{g}$ dry weight. Amylose content of 24% has been reported for the Monthan and Karpuravalli cultivars, while Saba and Nendran cultivars showed significantly higher amylose content of 35-36% (Kumar et al., 2019)

Resistant starch (RS) has been linked to various health advantages, including a reduced glycemic response, increased satiety, and a potential prebiotic effect (Bello-Pérez et al., 2018). In the current study, both cultivars exhibited 44% RS content and 43% digestible starch. The similar characteristics observed in both cultivars could be attributed to their belonging to the same genome ABB. Li et al. (2020) had reported a RS content of 42.33 % for unripe Taiwanese banana Pei Chiao.

Thermal properties- differential scanning calorimetry

The thermal properties of unripe banana flour play a crucial role in determining the functional characteristics of various food products. The gelatinization characteristics are summarized in Table 2. The gelatinization temperature of banana flour ranged from 85.6 to 88.37 °C. Notably, Monthan flour exhibited a higher gelatinization temperature of 88.37 °C, accompanied by an enthalpy of gelatinization of 253.5 J/g. Conversely, Peyan flour displayed a ΔH value of 210.8 J/g.

Gelatinization temperature in the range of 77.49 to 79.99°C was reported for different varieties of unripe banana, namely Saba, Mas and Berangan (Mamat et al., 2021). In a research study Monthan flour had higher gelatinization temperature of 111.81 ± 1.02 °C with the enthalpy of gelatinization 418.81 ± 1.72 J/g and the researchers appreciate this characteristic that renders unripe banana flour potentially beneficial in products requiring delayed pasting, such as extruded snacks (Kumar et al., 2019).

CONCLUSION

The underexplored potential of green bananas, despite widespread domestic consumption, emphasizes the need to diversify their applications, especially in flour production. This strategic focus is crucial for advancing innovations in functional foods. The study delved into examining the starch characteristics of unripe banana flours derived from *Musa* cultivars Peyan and Monthan. This investigation sheds light on the potential suitability of these flours as supplements in various food products. The Peyan and Monthan UBF varieties, with total starch contents of $86.47 \pm 3.05\%$ and $82.94 \pm 3.05\%$, respectively, exhibited a 23% amylose content. Both cultivars displayed 44% resistant starch and 43% digestible starch, making them suitable for low glycemic products. Their elevated gelatinization temperature of 85.6 to 88.37 °C suggests promising scope for utilization in high-temperature processed foods like pasta and noodles. The unique B-type starch diffraction pattern with a relative crystallinity percentage of 8.91%-13.06% and the higher resistant starch content make these UBFs less susceptible to enzymatic degradation, positioning them well for gut health and diabetic foods. The study strongly advocates for further research to explore the utilization of unripe banana flour from both Peyan and Monthan cultivars in food product development.

ACKNOWLEDGEMENT

The authors extend their gratitude to the following institutions for their valuable contributions to the research: the Sophisticated Analytical Instruments Facility (SAIF) at the Indian Institute of Technology Madras (IITM) in Chennai for conducting SEM and DSC analysis, the CNR Rao Research Centre at Avinashilingam Institute for Home Science and Higher Education for Women in Coimbatore for performing FTIR and XRD analysis, and M.O.P. Vaishnav College for Women in Chennai for providing the necessary research facilities for the experimental work.

REFERENCE

- Ahmed, Z.F.R., Taha, E., Abdelkareem, N.A., & Mohamed, W.M. (2020). Postharvest properties of unripe bananas and the potential of producing economic nutritious products. *International Journal of Fruit Science*, 20(sup2), S995–1014. <https://doi.org/10.1080/15538362.2020.1774469>
- Anajekwu, E.O., Maziya-Dixon, B., Akinoso, R., Awoyale, W., & Alamu, E.O. (2020). Physicochemical properties and total carotenoid content of high-quality unripe plantain flour from varieties of hybrid plantain cultivars. *Journal of Chemistry*, Article ID 5960346: 2020. <https://doi.org/10.1155/2020/5960346>

- Association Official Analytical Chemist [AOAC]. (n.d.). Official methods of analysis. 18th edn. Method 2002.02. Resistant starch in starch and plant materials.
- Bello-Pérez, L.A., Flores-Silva, P.C., Agama-Acevedo, E., & Tovar, J. (2018). Starch digestibility: past, present, and future. *Journal of the Science of Food and Agriculture*, 100(14), 5009–16. <https://doi.org/10.1002/jsfa.8955>
- Campuzano, A., Rosell, C.M., & Cornejo, F. (2018). Physicochemical and nutritional characteristics of banana flour during ripening. *Food Chemistry*, 256, 11-17. <https://doi.org/10.1016/j.foodchem.2018.02.113>
- Cornejo-Ramírez, Y.I., Martínez-Cruz, O., Del-Toro-Sánchez, C.L., Wong-Corral, F.J., Borboa-Flores, J., & Cinco-Moroyoqui, F.J. (2018). The structural characteristics of starches and their functional properties. *Cyta-journal of Food*, 16(1), 1003–17. <https://doi.org/10.1080/19476337.2018.1518343>
- FAO. (2022). *Banana Market Review – Preliminary results 2022*. Rome. Banana Market Review (fao.org).
- Goñi, I., García-Alonso, A., & Saura-Calixto, F. (1997). A starch hydrolysis procedure to estimate glycemic index. *Nutrition Research*, 17(3), 427–37. [https://doi.org/10.1016/s0271-5317\(97\)00010-9](https://doi.org/10.1016/s0271-5317(97)00010-9)
- Khoza, M., Kayitesi, E., & Dlamini, B.C. (2021). Physicochemical characteristics, microstructure and health promoting properties of green banana flour. *Foods*, 10(12), 2894. <https://doi.org/10.3390/foods10122894>
- Kumar, P.S., Saravanan, A., Narayanan, S., Shiva, K.N., Ravi, I., Mayilvaganan, M., et al. (2021). Exploring differences in the physicochemical, functional, structural, and pasting properties of banana starches from dessert, cooking, and plantain cultivars (*Musa* spp.). *International Journal of Biological Macromolecules*, 191, 1056–67. <https://doi.org/10.1016/j.ijbiomac.2021.09.172>
- Kumar, P.S., Saravanan, A., Sheeba, N., & Uma, S. (2019). Structural, functional characterization, and physicochemical properties of green banana flour from dessert and plantain bananas (*Musa* spp.). *LWT*, 116, 108524. <https://doi.org/10.1016/j.lwt.2019.108524>
- Li, M.C., Chou, C.F., Hsu, S.C., & Lin, J. (2020). Physicochemical characteristics and resistant starch of different varieties of banana from Taiwan. *International Journal of Food Properties*, 23(1), 1168–75. <https://doi.org/10.1080/10942912.2020.1788077>
- Mamat, H., Addrian, I., Adawiyah, Z.U.B., Mansoor, A.H., & Zainol, M.K. (2021). Evaluation of physicochemical and functional characteristics of flour from three cultivars of unripe banana (*Musa* sp.) cultivated in Sabah, Malaysia. *Food Research*, 5(4), 135–44. [https://doi.org/10.26656/fr.2017.5\(4\).642](https://doi.org/10.26656/fr.2017.5(4).642)
- Marta, H., Cahyana, Y., Djali, M., Arcot, J., & Tensiska, T. (2019). A comparative study on the physicochemical and pasting properties of starch and flour from different banana (*Musa* spp.) cultivars grown in Indonesia. *International Journal of Food Properties*, 22(1), 1562-75. [doi10.1080/10942912.2019.1657447](https://doi.org/10.1080/10942912.2019.1657447)
- McCready, R.M., Guggolz, J., Silveira, V., & Owens, H.S. (1950). Determination of starch and amylose in vegetables. *Analytical Chemistry*, 22(9), 1156-8. <https://doi.org/10.1021/ac60045a016>

- Ouyang, Q., Wang, X., Xiao, Y., Luo, F., Lin, Q., & Ding, Y. (2021). Structural changes of A-, B- and C-type starches of corn, potato, and pea as influenced by sonication temperature and their relationships with digestibility. *Food Chemistry*, 358, 129858. <https://doi.org/10.1016/j.foodchem.2021.129858>
- Padhi, S., & Dwivedi, M. (2022). Physico-chemical, structural, functional, and powder flow properties of unripe green banana flour after the application of Refractance window drying. *Future Foods*, 5, 100101. <https://doi.org/10.1016/j.fufo.2021.100101>
- Thanyapanich, N., Jimtaisong, A., & Rawdkuen, S. (2021). Functional Properties of Banana Starch (*Musa* spp.) and Its Utilization in Cosmetics. *Molecules*, 26(12), 3637. <https://doi.org/10.3390/molecules26123637>
- Von Loesecke, H.W. (1950). *Bananas: chemistry, physiology, technology*. Interscience Publishers, No. 634.772/V947