CHAPTER 1

INTRODUCTION

Chapter 1

Introduction

1.1 Background

Coconut (*Cocos nucifera L.)* is a popular tropical plant grown in more than 90 countries; India, Philippines and the Indonesia are the major producers of coconut in the world, accounting for 75% of total world production (Alyaqoubi et al., 2015). India Brand Equity Foundation (2022) reported that India contributed approximately 31.45% to the total worldwide output of coconut during 2021-22 with a substantial production of 19,247 million nuts. The coconuts are used for copra processing, coconut oil extraction, and coir manufacturing.

Coconut is in great demand for its tender water, oil, meat, and milk. Coconut milk is obtained after direct squeezing or addition of water; the extracted milk has fat, protein, and carbohydrate (Wang et al., 2020). It is an important ingredient in Asian cooking as well as other cuisines throughout the globe. Several factors affect coconut milk composition, including variety, age, coconut growth environment, cultural customs, preparation technique, and extraction process variables, such as temperature and extent of water addition (Tangsuphoom and Coupland, 2005). Coconut milk has several vitamins, electrolytes, and minerals, including calcium, potassium, and chloride. Coconut milk is reported to reinforce the body's immune system (Benaissa et al., 2019). The major fatty acid present in coconut oil was Lauric acid, has been reported to inhibit neuroinflammation and provide an efficient cellular antioxidant activity, which protects the cells (Ramya et al., 2022). Coconut milk (CM) normally contains around 54% moisture, 35% fat, and 11% solid non-fat, and is classified as an oil in water emulsion. It is stabilized by naturally existing proteins like globulins, albumins and phospholipids like cephalin and lecithin.

Within five to ten hours of manufacturing, natural CM separates into cream and serum layers (Tangsuphoom and Coupland, 2005; Jirapeangtong et al. 2008). The separation of CM into water and cream phase is considered as the actual defect of CM and several techniques have been developed to stabilize the emulsion. Many factors account for the stability of the oil in water emulsion like fat content, type of stabilizing agents used, homogenizing pressure, and thermal process conditions. Marina et al. (2009) reported that during the virgin coconut oil extraction by chilling method, coconut milk is subjected to centrifugation to separate the coconut cream from the aqueous phase (coconut skim milk). The aqueous phase known as CM whey is a protein-rich (2-3%) by-product of virgin coconut oil industry and is presently being discarded in the environment without any value addition (Adsare and Annapure, 2021). This

plant-based milk is free from lactose and cow's milk protein as well as allergenic constituents, that are otherwise present in plant milk sources, like peanuts, almonds, and soybean (Rao and Khanum, 2016). Value addition of coconut milk as a beverage has not been extensively studied. As coconut milk is a low acid liquid, there is scope for addition of an acidic juice and give value addition to the bland coconut milk in terms of taste, nutrition, stability, and novelty.

In terms of global output, pineapples (Ananas comosus) are the second most produced tropical fruit (Ansari and Jamaluddeen, 2023). India is positioned as the sixth-largest pineapple producer globally, and contributes significantly with an annual output of 1.8 million tonnes. Notably, pineapple cultivation in India is prominent in the North-Eastern states (Assam, Nagaland, Manipur, Tripura, Meghalaya, Mizoram, Arunachal Pradesh), Kerala, West Bengal, Karnataka, Bihar, Goa, and Maharashtra (Ansari and Jamaluddeen, 2023). Pineapples have sweet and acidic flavour and are consumed widely. Pineapple juice is a rich source of polyphenolic compounds such as ferulic acid, gallic acid and chlorogenic acid, which are considered to have antimutagenic, anticarcinogenic, antioxidant, antidiabetic, and antihypertensive effects, and play an effective role against cataracts and cardiovascular diseases (Islam et al., 2021). This juice is a good candidate for developing a ready-to-serve blended beverage with coconut milk.

Blended beverage using fruit juice are currently gaining popularity among consumers as a convenient method to eat fruits. Soy milk and cow milk are two of the key nutritional components in these drinks (Quan et al., 2020). However, coconut milk-based blended beverage has not been extensively investigated and reported. Phase separation or serum separation, which happens during formulation and storage because of casein aggregation at low pH, is one of the main problems with acidified milk beverages. Hydrocolloids are high-molecular weight hydrophilic biopolymers and can be used to prevent serum separation (Tangsuphoom and Coupland, 2008). High pressure homogenization (HPH) can be considered as a key technique in preventing pulp sedimentation due to the reduction in particle size during homogenization (Kubo et al., 2013).

However, one of the main concerns for food safety while manufacturing beverage is the control and prevention from development and spoiling of harmful bacteria. Several outbreaks caused by pathogenic microorganisms like, *Listeria monocytogenes, Salmonella, Escherichia coli, Bacillus cereus,* etc, are documented to be related to unpasteurized juice (Deshaware et al., 2019). Thermal treatments that inactivate microorganisms and enzymes are the most common way to extend the shelf life of liquid foods. However, heat causes irreversible loss of nutritional

compounds, undesirable changes in physicochemical properties, and alteration of their antioxidant properties (Zulueta et al., 2013). Therefore, the task is to develop a proper thermal inactivation procedure that maximizes the elimination of pathogenic and spoilage bacteria while causing the least amount of collateral damage to the product flavour, colour, and nutritional value (Deshaware et al., 2019).

It has been suggested that non-thermal methods are an excellent choice for creating food items with a fresh-like look while maintaining their nutritional value. Researchers have examined the possibility of HPH treatment (between 200 and 300 MPa) inactivates the pathogenic and spoilage microorganisms as a substitute for thermal treatments to lengthen the shelf life of juice. For instance, the use of HPH treatments increased the shelf life of commercial fruit juices (pineapple, orange and red orange) to several weeks by dramatically reducing *Escherichia coli, Listeria innocua,* and *Staphylococcus carnosus* (Maresca et al., 2011).

Curcumin is a bioactive pigment obtained after the extraction and purification of ground rhizomes of turmeric. Curcumin has anti-inflammatory, antimicrobial, antirheumatic, immunomodulatory, and anti-tumour effects (Liu et al., 2018). Several attempts have been made to overcome low oral bioavailability of curcumin, and in order to do so, researchers have created a large variety of novel formulations (Liu et al., 2018). Several systems have been explored for their capability to encapsulate and carry curcumin, including microemulsions, nanoemulsions, solid lipid nanoparticles, liposomes, biopolymer nanoparticles, and microgels. Among these delivery systems, nanoemulsions have received more consideration because of their possible benefits over traditional emulsions. Nanoemulsions contain moderately small particles and so they have high optical clarity that can be incorporated into different products that should be transparent or just somewhat turbid, for example, many fortified waters, soft drinks, and fruit juices (Yu and Huang, 2012). Limited amount of curcumin can be successfully incorporated within the droplets in surfactant-stabilized nanoemulsions. The concentration of curcumin should always remain below the saturation limit; crystal growth occurs if curcumin content is increased due to very low quantity of oil present in the nanostructure, which increases the average droplet size of the nanoemulsion and subsequently destabilizes the system (Lund and Pantuso, 2014). On the other hand, Pickering particle-stabilized emulsions have been reported to encapsulate more amount of curcumin and do not show alteration in droplet size after curcumin incorporation and storage (Neves et al., 2020).

In Pickering emulsions, solid colloidal particles can irreversibly adsorb at liquid interfaces and stabilize the system. Nanocellulose derived from natural and renewable materials have been

reported to stabilize emulsions (Chiewchan et al., 2006). Nanocellulose can absorb at the interface between oil and water, creating a steric barrier around the emulsion droplet to stop it from coalescing (Pengon et al., 2018). Various sources used for synthesizing nanocellulose are woody and non-woody materials (tomato peel, pea hull, etc.), and agricultural residues (straw, coconut and rice husk, pineapple leaf, banana rachis, etc.) (Esatbeyoglu et al., 2012). There are no reports on the use of cellulose present in the coconut meat residue that is obtained as a by-product after the extraction of milk to stabilize a Pickering emulsion.

It is hypothesized that defatted coconut milk can be used to develop a novel blended beverage with pineapple juice and can be used as a medium to deliver curcumin for improved absorption in nanoemulsified form that is stabilized with nanocellulose derived from coconut milk waste residue and oil from coconut cream. It is also hypothesized that high-pressure homogenization will deliver a stable nanoemulsified beverage which shows enhanced bioaccessibility for curcumin.

Our aim of this work was to blend defatted coconut milk (aqueous phase) with pineapple juice and analyze the developed beverage for sensorial, biochemical, and nutritional properties as well as to process the blended beverage for shelf stability. Further, a curcumin-enriched and nanocellulose-stabilized Pickering nanoemulsion was formulated via oil in water emulsion approach using virgin coconut oil that was extracted from the coconut meat and nanocellulose that was synthesized from coconut meat residue, and the developed emulsion and nanocellulose were characterised. Another aim of the research was to analyse the Pickering nanoemulsion incorporated blended beverage for particle size, microstructure, stability, in vitro bioaccessibility of curcumin, microbial stability, and effect of storage.

1.2 Objectives of the thesis

Following specific objectives were undertaken to achieve the main aims of the research work:

1. To develop and evaluate defatted coconut milk and pineapple juice-based blended beverage.
2. To determine the effect of pasteurization and high-pressure homogenization on microbial stability during storage of the blended beverage.
3. To characterize curcumin-enriched Pickering nanoemulsion stabilized with nanocellulose synthesized from coconut milk residue.
4. To characterize the blended beverage incorporated with curcumin-enriched Pickering nanoemulsion.

Bibliography

Adsare, S. R., and Annapure, U. S. (2021). Microencapsulation of curcumin using coconut milk whey and Gum Arabic. *Journal of Food Engineering*, 298:110502.

Alyaqoubi, S., Abdullah, A., Samudi, M., Abdullah, N., Addai, Z. R., and Musa, K. H. (2015). Study of antioxidant activity and physicochemical properties of coconut milk (Pati santan) in Malaysia. *Journal of Chemical and Pharmaceutical Research*, 7(4):967–973.

Ansari, M. N. and Jamaluddeen. (2023). Technical efficiency and cost reduction in pineapple cultivation: A study on the pineapple growers of North Bengal. *Research Journal of Agricultural Sciences*, 14(5):1147–1150.

Benaissa, Y., Addou, S., Dib, W., Benhatchi, S., Mehidi, A., Kheroua, O., and Saidi, D. (2019). Effect of in vitro hydrolysis on coconut milk digestibility. *Revue Francaise d'Allergologie*, 59(5):380–384.

Deshaware, S., Gupta, S., Singhal, R., and Variyar, P. S. (2019). Influence of different pasteurization techniques on antidiabetic, antioxidant and sensory quality of debittered bitter gourd juice during storage. *Food Chemistry*, 285:156–162.

Esatbeyoglu, T., Huebbe, P., Ernst, I. M., Chin, D., Wagner, A. E., and Rimbach, G. (2012). Curcumin from molecule to biological function. *Angewandte Chemie International Edition*, 51(22):5308–5332.

Indian Brand Equity Foundation (June 2022). Coconut Industry and Exports. Retrieved on 14 Nov. 2023 from https://www.ibef.org.

Islam, M. Z., Tabassum, S., Harun Rashid, M., Vegarud, G. E., Alam, M. S., and Islam, M. A. (2021). Development of probiotic beverage using whey and pineapple (Ananas comosus) juice: Sensory and physico-chemical properties and probiotic survivability during in-vitro gastrointestinal digestion. *Journal of Agriculture and Food Research*, 4:100144.

Jirapeangtong, K., Siriwatanayothin, S., and Chiewchan, N. (2008). Effects of coconut sugar and stabilizing agents on stability and apparent viscosity of high-fat coconut milk. *Journal of Food Engineering*, 87(3):422–427.

Liu, Y., He, C., and Song, H. (2018). Comparison of fresh watermelon juice aroma characteristics of five varieties based on gas chromatography-olfactometry-mass spectrometry. *Food Research International*, 107:119–129.

Lund, K. C., and Pantuso, T. (2014). Combination effects of quercetin, resveratrol and curcumin on in vitro intestinal absorption. *Journal of Restorative Medicine*, 3(1): 112–120.

Ma, Z., Wang, N., He, H., and Tang, X. (2019). Pharmaceutical strategies of improving oral systemic bioavailability of curcumin for clinical application. *Journal of Controlled Release*, Vol. 316, pp: 359–380.

Maresca, P., Donsì, F., and Ferrari, G. (2011). Application of a multi-pass high-pressure homogenization treatment for the pasteurization of fruit juices. *Journal of Food Engineering*, 104(3):364–372.

Marina, A. M., Che Man, Y. B., Nazimah, S. A. H., and Amin, I. (2009). Antioxidant capacity and phenolic acids of virgin coconut oil. *International Journal of Food Sciences and Nutrition*, 60:114–123.

Marina, A. M., Che Man, Y. B., Nazimah, S. A. H., and Amin, I. (2009). Chemical properties of virgin coconut oil. *JAOCS, Journal of the American Oil Chemists' Society*, 86(4):301–307.

Neves, M. F., Trombin, V. G., Marques, V. N., and Martinez, L. F. (2020). Global orange juice market: a 16-year summary and opportunities for creating value. *Tropical Plant Pathology*, 45:166–174.

Owolade, S. O., Akinrinola, A. O., Popoola, F. O., Aderibigbe, O. R., Ademoyegun, O. T., and Olabode, I. A. (2017). Study on physico-chemical properties, antioxidant activity and shelf stability of carrot (Daucus carota) and pineapple (Ananas comosus) juice blend. *International Food Research Journal*, *24*(2).

Pengon, S., Chinatangkul, N., Limmatvapirat, C., and Limmatvapirat, S. (2018). The effect of surfactant on the physical properties of coconut oil nanoemulsions. *Asian Journal of Pharmaceutical Sciences*, 13(5): 409–414.

Quan, W., Tao, Y., Qie, X., Zeng, M., Qin, F., Chen, J., and He, Z. (2020). Effects of high-pressure homogenization, thermal processing, and milk matrix on the in vitro bioaccessibility of phenolic compounds in pomelo and kiwi juices. *Journal of Functional Foods*, 64:103633

Ramya, V., Shyam, K. P., Kowsalya, E., Balavigneswaran, C. K., and Kadalmani, B. (2022). Dual roles of coconut oil and its major component lauric acid on redox nexus: focus on cytoprotection and cancer cell death. *Frontiers in Neuroscience*, 16:833630.

Rao, P. J., and Khanum, H. A. (2016). Green chemistry approach for nanoencapsulation of bioactive compound - Curcumin. *LWT- Food Science and Technology*, 65: 695–702,

Tangsuphoom, N., and Coupland, J. N. (2008). Effect of pH and ionic strength on the physicochemical properties of coconut milk emulsions. *Journal of Food Science*, 73(6):E274–E280.

Wang, W., Chen, H., Ke, D., Chen, W., Zhong, Q., Chen, W., and Yun, Y. H. (2020). Effect of sterilization and storage on volatile compounds, sensory properties and physicochemical properties of coconut milk. *Microchemical Journal*, 153:104532.

Yu, H., and Huang, Q. (2012). Improving the oral bioavailability of curcumin using novel organogel-based nanoemulsions. *Journal of Agricultural and Food Chemistry*, 60(21):5373–5379.

Zulueta, A., Barba, F. J., Esteve, M. J., and Frígola, A. (2013). Changes in Quality and Nutritional Parameters During Refrigerated Storage of an Orange Juice-Milk Beverage Treated by Equivalent Thermal and Non-thermal Processes for Mild Pasteurization. *Food and Bioprocess Technology*, 6(8):2018–2030.