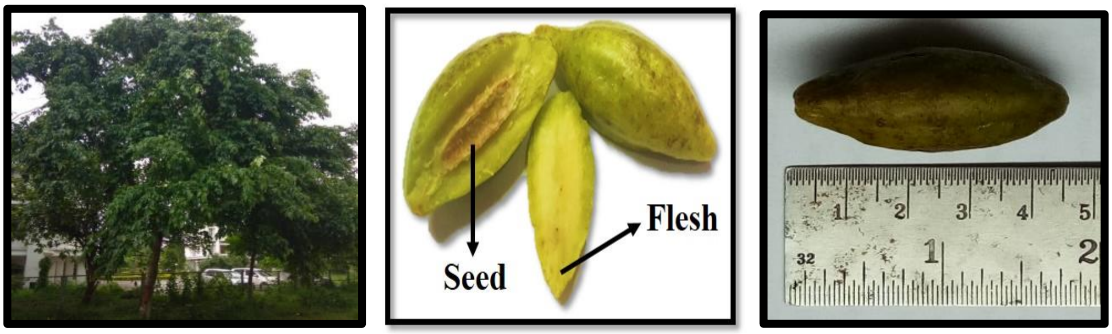
Chapter-2

Review of Literature

2.1. Historical background and Origin

Terminalia chebula Retzius (Haritaki) is widely cultivated in South East Asia including India [39]. It is a perennial tree belonging to the *Terminalia* genus, and well-known revitalising plant that grows as a medium to big tree throughout tropical and subtropical Asia, including China, Bangladesh, Bhutan, and Tibet. This tree may be found in Northern India's woods and locations with little rainfall, such as Uttar Pradesh and Bengal, as well as Tamil Nadu, Karnataka, and Southern Maharashtra. F**ig. 2.1** represent the fruit and seed of the haritaki tree. Haritaki, the edible fruit, blooms from April to August and ripens from October to January. The fruit is drupe-like, 2–4.5 cm long and 1.2–2.5 cm wide, blackish or yellowish-brown, wrinkled, and has five longitudinal ridges [179].



(a) **(b)** **(c)**

Fig. 2.1. (a) Haritaki tree (b) Fruit with seed and flesh (c)*Terminalia chebula* (Haritaki)

It is known in Tibet as the "King of Medicine," and its exceptional therapeutic qualities have placed it at the top of the Ayurvedic Materia Medica list [171]. Except for salt, the fruit of haritaki contains five other tastes: spicy outer peel, sour ridge, astringent seed, bitter stem, and sweet endosperm [179]. It is referred to as a hub of medicinal activities and an important ethnomedicinal plant of human society. It has been used as a medication to treat ailments since antiquity. It is a rich source of phytochemicals that could be a good therapeutic alternative and other chemical components; but it is particularly high in tannins (32-34%) which contributes the bitter and astringent taste and the main reason for its rare acceptance among the consumer [106]. Fresh fruit, dried pulp, seed and powder of different varieties of haritaki is presented in **Fig. 2.2.** Haritaki intake may not only meet nutritional needs, but also play an important part in nutraceutical development.

(a) **(b)** **(c)** **(d)**

Fig. 2.2. Fresh fruit, dried pulp, seed and powder of different varieties of haritaki (a) Ellipse shape, (b) Oval shape, (c) Small ellipsoid shape, (d) Ellipsoid shape haritaki (Image courtesy: Tezpur University, India)

As a result, the food and flavour industries are looking for novel food components to use in the development of food supplements. The consumption of haritaki may also aid in the fulfilment of nutritional needs and the cure of many non-communicable illnesses. Plant compounds have biological roles and may display physiologically relevant chemistry in human systems, resulting in less adverse effects [103]. Botanical classification of haritaki is given in **Table 2.1** [51].

Table 2.1. Botanical classification of haritaki

Botanical Name	*Terminalia chebula Retz.*
Kingdom	Plantae
Division	Phanerogams
Class	Monocotyledons
Order	Scytaminiales
Family	Combretaceae
Genus	Terminalia
Species	Chebula

2.2. Bioactive compound present in Haritaki

Reddy et al. [172] reported that, haritaki increases the appetite acting as a digestive aid, liver stimulant and has a mild laxative effect. Additionally, it strengthens the body, awakens the senses, and removes waste products from the body like urine and stools [39]. The ethanol extract of haritaki fruit exhibited a significant inhibitory effect on cellular aging [139]. Yin et al. [218] reported that the majority of plant-derived phytochemicals, including phenolic compounds and flavonoids, have been shown to have a beneficial effect on health. Both Ayurveda and Unani stress the value of medicinal plants in lowering the risk of various lifestyle illnesses, including cancer and cardiovascular disease, as well as other conditions, including rheumatoid arthritis, lung conditions, cataracts, Parkinson's or Alzheimer's disease, and also improving liver function [139]. One of the key endogenous phenolic acids present in the haritaki plant that has anti-inflammatory properties is gallic acid. The bioactive components and haritaki's actions are listed in **Table 2.2**.

Table 2.2. Bioactive compounds of haritaki and their activities

Sl. No.	Bioactive compounds	Activities	References
1.	Gallic acid	Antioxidant, antibacterial, antiviral, cytoprotective activity	Sato et al. [180]
2.	Chebulic acid	Hepatoprotective, antioxidant and free radical scavenging activity	Lee et al. [110]
3.	Ellagic acid	Antibacterial activity against intestinal Clostridium perfringens, *Escherichia coli*; antiproliferative activity	Saleem et al. [179]
4.	Neochebulic acid	Hepatoprotective, antioxidant and free radical scavenging activity	Lee et al. [112]
5.	Chebulagic acid	Cytoprotective, anti-arthritic activity	Sato et al. [180]
6.	Hydroxybenzoic acid derivatives	Antioxidant activity	
7.	Hydroxycinnamic acid derivatives	Antioxidant activity	Chen et al. [40]
8.	Flavonol aglycones	Antioxidant activity	
9.	Chebulinic acid	Antiproliferative activity	
10.	2, 4-chebulyl-beta-D-glucopyranose	Antiproliferative activity	Saleem et al. [179]

Phenolic compounds include both molecules with just one phenol ring, such as phenolic acids and phenolic alcohols, and molecules with several hydroxyl groups on aromatic rings. Based on the number of phenol rings they contain and the structural elements that link these rings, polyphenols are divided into several classes. The five main groups of polyphenols are flavonoids, phenolic acids, tannins (hydrolysable and condensed), stilbenes, and lignans [43].

Phenolic acids make up roughly a third of all dietary phenols, and they may be found in both free and bound forms in plants [173]. Through ester, ether, or acetal linkages, bound-phenolics can be connected to a variety of plant components [220]. The various types of phenolic acids have varied levels of appropriateness for various extraction conditions and susceptibilities to degradation [175]. Two phenolic acid subgroups are the hydroxybenzoic and hydroxycinnamic acids. Gallic, p-hydroxybenzoic, protocatechuic, vanillic, and syringic acids all have the same (C_6-C_1) structure with hydroxybenzoic acids. The most common examples of hydroxycinnamic acids are caffeic, ferulic, p-coumaric, and sinapic acids, which are aromatic compounds with a three-carbon side chain (C_6-C_3) [27].

Tannins are classified into two types: hydrolysable and condensed tannins. Tannins are relatively high molecular compounds that make up the third most significant category of phenolics [163]. Polymeric flavonoids known as proanthocyanidins (condensed tannins) are polymeric flavonoids. Although the metabolic routes for flavonoids are well recognised, the processes leading to condensation and polymerization remain unknown. Flavan-3-ols (-)-epicatechin and (+)-catechin are the most frequently researched condensed tannins.

Gallic acid is derivatives of hydrolysable tannins and is esterified to a core polyol, then the galloyl groups are esterified or oxidatively crosslinked to produce more complicated hydrolysable tannins [72]. Gallic acid is a kind of endogenous phenolic acid found in the *T. chebula* plant that has anti-inflammatory properties. A third subgroup, phlorotannins, has been isolated from many species of brown algae and consists solely of phloroglucinol [163], although they are not significant in the human diet [27]. Tannins are potential metal ion chelators, protein precipitating agents, and biological antioxidants, thus they have a variety of impacts on biological systems. Because tannins may play a wide range of biological activities and have such a wide structural diversity, it's been challenging to build models that can accurately anticipate their effects in any system. The primary elements of tannin include gallic acid, corilagin, ellagic acid, chebulic acid, chebulinic acid, and chebulagic acid. From haritaki, significant chemicals such as punicalagin, chebulanin, corilagin, neochebulinic acid, ellagic acid, chebulegic acid, chebulinic acid, 1,2,3,4,6-penta-ogalloyl-D-glucose, casuarinin, 3,4,6-tri-o-galloyl-D-glucose, ethyl gallate [91]. According to current research, Anthraquinones, ethaedioic acid, sennoside, 4,2,4 chebulyl-d-glucopyranose, terpinenes, and terpinenols are among the phytochemicals that have been reported [51]. It is a good source of vitamin C as well as a variety of minerals [123]. These bioactive compounds allowed them to play an essential role in plant development and reproduction, as well as offering effective defence against diseases and predators [27]. In addition to contributing to the colour and sensory qualities of fruits [6, 132, 201].

Flavonols, flavones, flavanones, flavanols (or catechins), isoflavones, flavanonols, and anthocyanidins are the most commonly occurring and structurally varied flavonoid classes [80], with flavones and flavonols being the most widely occurring and structurally diverse [76]. Within each family of flavonoids, substitutions to rings A and B result in distinct molecules [160]. Oxidation, alkylation, glycosylation, acylation, and sulphonation are some of the possible replacements [18]. Due to their high redox potential, flavonoids may function as reducing agents, hydrogen donors, and singlet oxygen quenchers, making them particularly valuable antioxidants. They also have the ability to chelate metals [201].

2.3. Drying kinetics of some fruits and vegetables

Drying kinetics of various plant materials have been extensively studied by previous authors and the effects of air conditions (air temperature, air humidity, and air velocity), typical sample size, and drying kinetics were also examined [129]. The GAB equation was fitted using a first-order reaction kinetics model. The drying sample size and air conditions were shown to have a significant impact on the parameters of the model under consideration. In instance, the temperature rise lowers the equilibrium moisture content of the dehydrated items and raises the drying constant. The impact of hot air drying and refractance window (RW) on blueberry pulp and the drying kinetics as defined by the Page and Fick Models was published by Rurush et al. [177]. The findings demonstrated that the Page model provided the best match, with temperature-dependent increases in the diffusivity and consistency (k) parameters, drying at 95°C. Compared to hot air drying, the RW approach reduced drying time and overall time by 30%. The impact of the freeze drying on the pulp of the cranberries was documented by Rudy et al. [176]. The procedure was carried out in the drying chamber at various temperatures of 30, 50, and 70°C, respectively. According to the findings, drying kinetics were lowered by around 50%. The models by Page, Wang, and Singh were the most appropriate for describing the freeze-drying of cranberry pulp. Antioxidant activity is negatively impacted by drying temperature; as drying temperature increased, antioxidant activity decreased across the board for all samples.

2.4. Moisture sorption isotherm (MSI) of some fruits and vegetables

Studies on the MSI of food are especially interesting since they provide helpful advice on drying, aeration, and storage settings. MSI studies are crucial thermodynamic tools for forecasting how water and food components interact. With the aid of the MSI study, it is also possible to predict the information on maximum stability during packaging and storage. Using a conventional static-gravimetric method at five different temperatures (25-45°C), the moisture sorption isotherm of vacuum dried culinary banana flour was examined [98]. Between 0.1 and 0.65 water activities (aw), equilibrium moisture content (EMC) gradually increased; however, after EMC exceeded 0.65 aw, type II isotherms with sigmoidal characteristics resulted. At $P > 0.05$, the relationship between temperature and EMC was not significant. Out of the seven models that were fitted, the Peleg model had the highest coefficient of determination (R^2), the lowest relative deviations and best suited the criteria for the model. The Clausius-Clapeyron equation was used to calculate the net isosteric heat of sorption (Qst), which revealed a diminishing trend with rising EMC. Furthermore, the stability of the polyphenols and antioxidants in culinary banana flour, which was tested at 25°C, revealed some modest degradation up to 120 days without altering its bioactive qualities. The review by Andrade et al. [10] states that the Peleg model consistently exhibits equal or higher appropriateness than the GAB model, which is consistent with our findings. As for predicting EMC of different starchy powders, such as potato [84], and pistachio nut [78] at various storage temperatures, several researchers have discovered the Peleg model to be the best suitable model. According to reports, Type II isotherms provide good models for starchy flours like tapioca, cassava, and unpeeled and peeled banana flour [22, 41, 157]. The moisture adsorption isotherms of the freeze-dried powders made up of different ratios of avocado, maltodextrin, and inulin were measured using the gravimetric static method of saturated salt solutions at 25 °C and a range of water activity from 0.11 to 0.86. The following sorption models were used to assess the data: Peleg, Lewicki, Oswin, Henderson, GAB (Guggenheim, Anderson, and deBoer), and Brunauer-Emmett-Teller (BET). The goodness of the fit is assessed using parameters like the root mean square values and the coefficient of determination. While curves plotted for other powders revealed sigmoid shape, the sorption isotherm of the pure avocado powder was III type. All of the tested mixes' sorption data were determined to be best represented by the Peleg model [60, 192].

2.5. Degradation of total phenolic content and antioxidant activity of some fruits and vegetables

Hardy kiwifruit (*Actinidia arguta*) puree was stored at 5, 15, 25, and 45 °C for 72 h to determine how the temperature affected the loss of total phenolic content (TPC) and antioxidant activity, according to Kim et al. [99]. Over time, the TPC and antioxidant activity of resilient kiwi puree decreased as the storage temperature rose. A first-order kinetic model described how total phenolic content and antioxidant activity degraded, and kinetic parameters including k, $t_{1/2}$, Q10, and E_a were derived. With increasing storage temperature, the k and $t_{1/2}$ values decreased, and the Q10 values for TPC and antioxidant activity were 1.43 and 1.43, respectively. These findings showed that the phenolic content and antioxidant activity of resilient kiwi puree strongly rely on temperature.

The levels of anthocyanins, the overall amount of phenolic compounds, and antioxidant activity were all measured. The compound's instability, which results in the breakdown process seen in experiments, was associated to changes in aromatic behaviour. These findings can be used to choose operating conditions that will limit TPC degradation and help researchers better understand how the electronic structural features of anthocyanin molecules affect that molecule's ability to degrade [119]. The quality metrics examined were significantly impacted by the storage of whole tomato at various temperature (2, 5, 10, 15 and 20 °C) settings. Significant changes in firmness, weight loss, and tomato green colour were seen. The findings also showed that chilling damage were caused by refrigeration storage at 2 and 5 °C and that the total phenolic content had slightly increased. The experimental data on colour characteristics (a* and hue value), hardness, and weight loss were well-fit by a fractional conversion model.

The Arrhenius law proved successful in describing the storage temperature effect. These findings serve as a solid predictive tool for estimating tomato quality at various points in the food chain. When using the kinetic model, a threshold of 55 °C for the colour parameter is calculated for tomato storage at 10, 15, and 20 °C for 30, 15, and 8 days, respectively. According to the findings, tomatoes (cv. "Zinac") stored at a temperature of 10 °C maintained their quality better, prevented chilling injuries, and had a longer shelf life [162]. This study looked into how microwave (MW) processing affected several bioactive components, moisture content, and antioxidant capacity. After being processed at three different MW output powers, Brussels sprouts underwent a kinetic analysis to determine how much total chlorophyll, vitamin C, total polyphenols, total flavonoids, antioxidant capacity, and two phenolic acids (sinapic and ferulic acid) degraded (460, 600, and 700 W).

The analysis of the bioactive components, moisture content, and antioxidant capability revealed that MW processing significantly decreased all of these variables. It was discovered that the outcomes of the HPLC study supported the findings of the spectroscopic examination. In order to fit the experimental data, zero-order and first-order kinetic models were used. The first-order kinetic model was determined to be the best one by R^2, RMSE, and χ^2. According to research by Nakilcioglu-Taş and Otleş [143], the MW output power of 460 W optimally conserved the bioactive components, moisture content, and antioxidant capability of Brussels sprouts. This is due to the fact that as the MW output power grew from 460 to 700 W, the degradation rate constant (k) for all examined parameters increased. Investigations were conducted into how storage duration and temperature affected the bioactive compounds. The findings revealed that vital nutrients were more stable at 4 °C than at 15 °C [155].

At 60, 70, 80, and 90°C for 7 hours, the impact of heating on the degradation of certain bioactive compounds and colour loss in raspberry pulp was examined. L-ascorbic acid and total monomeric anthocyanins had first-order kinetics, while total phenolics degraded according to a zero-order kinetic model. Hunter's a, b, and C values were used to explain the first-order reaction for the colour loss. L-ascorbic acid, total phenolics, and raspberry anthocyanins all had activation energies for degradation that were, respectively, 49.3, 15.7, and 32.2 kJ/mol. The colour loss process has higher activation energies (49.0-75.5 kJ/mol) than the other reactions, indicating that it is more sensitive to temperature increases [195].

2.6. Pre-treatment for extraction

Pre-treatment is generally performed to enhance the disruption of the cell wall and the extraction of bioactive compounds from the plant materials. In recent years, pre-treatments such as ultrasound, microwave, and enzymatic treatments have eased the extractability of the compounds from plant tissues. Recently, a number of authors have written about how different treatments, alone or together, greatly increased the amount of bioactive compounds that could be extracted [127, 133, 147].

In a study, the total phenolics content rose by about 4% in comparison to control after 10 min of high amplitude (70%) ultrasonic pretreatment (40 kHz frequency, 60% ethanol with 0.15% HCl, solvent to sample ratio 15:1). Prior to extracting flavour and colour from plant material, they were employed to pretreat the plant material [133]. The increased yield of bioactives extracted from various sources is the main benefit of enzyme-assistant extraction (EAE). Recent discoveries reporting an increase in the activity of various bioactives together with an increase in the production of bioactives have been seen in several research [127], and microwave pretreatment has improved extraction yield and polyphenol richness at the same time. In comparison to other substances, such as sugar and fibres, the accelerating effect of microwaves on extraction kinetics was more evident for polyphenols. Here, microwave pretreatments were suggested as a way to extract bio functionality while also improving product quality and quantity [9].

2.6.1. Extraction of bioactive compound

Modern "advanced" extraction technologies function better than conventional ones because the method of removing bioactive chemicals from medicinal plants is essential to providing consumers with a high-quality herbal product. One of the most crucial phases in the manufacturing of herbal goods is extraction since it has an impact on the active ingredients in the sample both qualitatively and quantitatively [81]. Given the wide range of chemical compounds that are physiologically active and plant species, screening techniques must be both traditional and thorough [61]. The separation, identification, and characterization of compounds that are physiologically active can only be done with the proper extraction techniques. Many factors influence the extraction of physiologically active chemicals, including the extraction technique, raw materials, and extraction solvent [199]. Extraction methods must be used under various situations to understand the selectivity of extraction from various natural sources. In recent years, there has been a lot of interest in extracting phenolic chemicals from natural sources separation, identification, and usages are all factors to consider [161]. Conventional, Non-conventional and Integration of different extraction techniques are presented in **Fig. 2.3**.

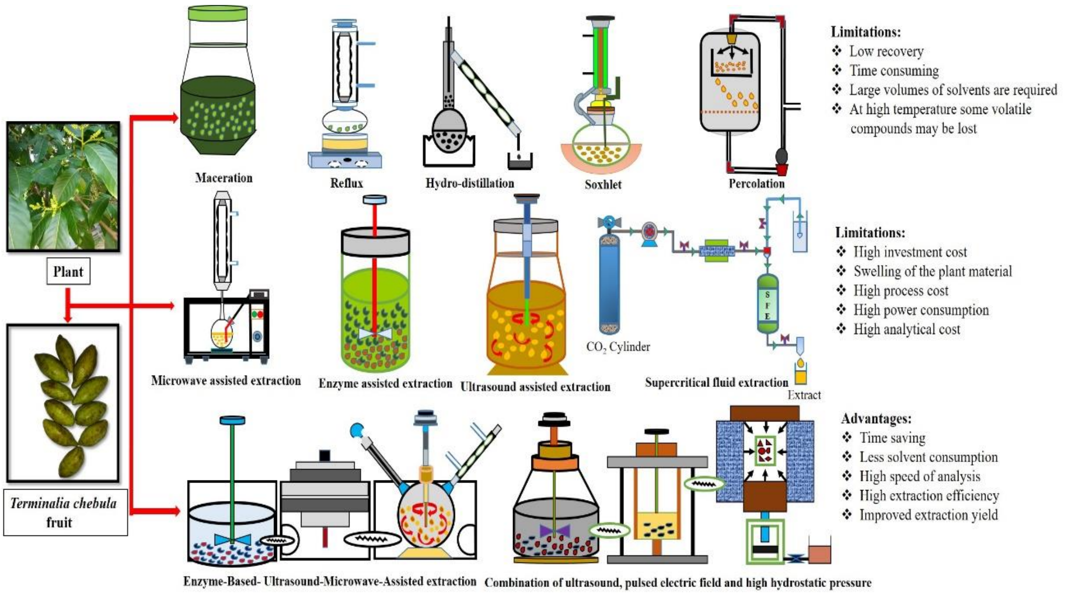


Fig. 2.3. Conventional, Non- conventional and Integration of different extraction techniques

2.6.1.1.Conventional extraction techniques

A variety of techniques are employed in extraction methods to separate biologically active chemicals from plant material and serve various purposes. These techniques are based on the various solvents' capacity for extraction and the manner of heating and/or stirring. When a lengthy extraction time is used, the loss of polyphenols has been seen by ionisation, hydrolysis, and oxidation during the extraction process [116].

2.6.1.1.1. Conventional reflux extraction (CRE)

Percolation or maceration, which need more extraction time and solvent, are less effective than conventional reflux extraction in terms of efficiency. It is not appropriate for extracting naturally occurring thermolabile compounds. The process of extracting total phenolic content from dried haritaki fruit was evaluated [202]. The conditions for the extraction were 76 °C, 76.4% ethanol, a solid-to-liquid ratio of 150 (mL/g), and an extraction time of 82 min. The whole pore volume of the material was also totally exhausted using two extraction cycle. The extract was filtered after being vacuum-extracted. When 60% ethanol was utilised as the extraction solvent, it was observed that the reflux approach outperformed the decoction process and produced the best yields of baicalin and puerarin. [222].

2.6.1.2. Non- conventional extraction techniques

One of the main issues with conventional extraction is how long it takes to complete, how thermosensitive chemicals are destroyed, and how expensive, pure solvents that evaporate quickly must be used [46]. Restrictions on extraction have forced the creation of a number of inventive and distinctive extraction techniques. Non-traditional extraction techniques sometimes go by the term of unconventional extraction techniques. Ultrasound, enzyme, microwave, pulsed electric field, supercritical fluid, and pressurised liquid are a few promising extraction methods. Green technologies are also used to describe processes that employ "green" practises. Along with these precautions, we may also use less risky chemical synthesis methods, like creating safer chemicals, employing secure solvent auxiliaries, utilising sustainable feedstock, and minimising derivatives [75].

2.6.1.2.1. Ultrasound-assisted extraction (UAE)

Ultrasound is a form of sound wave that people can hear but that is outside their usual hearing range. Frequencies in chemistry often vary from 20 kHz to 100 MHz. It compresses and expands a material in the same way that other waves do. The formation, development, and final bursting of bubbles is known as cavitation. The kinetic energy of motion can be turned into heating the contents of the bubble with a substantial quantity of energy. Bubbles have a temperature of around 5,000 K, a pressure of about 1,000 atmospheres, and a heating and cooling rate of more than 1010 K/s as calculated by Suslick and Doktycz [196]. Ultrasonic treatment in food processing is advantageous because it has the ability to reduce energy usage, save time, and extend product shelf life. Ultrasound may have an effect on plant cells and tissues, according to several studies, since the waves can elevate the temperature and then transmit the heat to the herb tissues [87].

The highest extraction of bioactive compounds from haritaki using ultrasound assisted extraction (UAE) was reported by Sheng et al. [184]. The ethanol concentration was set to 68%, the ultrasonic intensity was 3.6 W/cm^2, the solid-liquid ratio was 23 mg/mL, the particle size was 0.18 mm, and the treatment time kept as 20 min at 70 ℃, yielding 448.7±2.15 mg GAE/g DW total phenol, which confirmed the expected result (447.8 mg GAE/g DW). UAE extracts outperformed CSE extracts in terms of DPPH free radical and ABTS scavenging activities. Higher temperatures and longer treatment periods reduce antioxidant activity in conventional extraction techniques.

2.6.1.2.2. Supercritical fluid extraction (SFE)

The utilisation of supercritical fluid for extraction applications was explored by Zosel, who patented the decaffeination of coffee using SFE after Hannay and Hogarth discovered it in 1880 [226]. This method has been used in a variety of applications, including environmental, pharmaceutical, and polymer analysis, as well as food analysis [228]. Essential oils, flavonoids, total phenolic compounds, coumarins, and diterpenoids, as well as other useful components, may be extracted from a wide range of plants. Jha and Sit [90], reported the maximum extraction of bioactive compounds from haritaki using SFE, and the best circumstances for response surface methodology-desirability function (RSM-DF) were 3.34 mL/min, 166.94 bar, 51.97 °C, 67.47 min, 3.23 mL/min, 172.79 bar, 52.37 °C, 68.53 min, and 3.30 mL/min, 174.07 bar, 51.18 °C, 65.23 min for artificial neural network-genetic algorithm (ANN-GA).

2.6.1.3. Integration of different extraction techniques

The previous claim suggested that nowadays the pursuit of high-quality products with high bioactivity and minimal impact on human health and the environment is of paramount importance. Although each of the extraction techniques described in this chapter is effective on its own, using multiple of them simultaneously can yield even better outcomes. Additionally, this technique allows for the progressive extraction of distinct compounds from a sample and the purification of precious components from a variety of source materials [26]. See the list below for further information on some of the newly integrated new extractions for the extraction of chemicals of interest. Extraction methods have advanced rapidly thanks to recent rapid advancements. This is a strategy that primarily helps to conserve energy and resources by using sample preparation and analytical techniques together [137].

2.6.1.3.1. Ultrasound–Microwave-Assisted Extraction (UMAE)

Ultrasonic-microwave synergistic extraction (UMSE), also known as ultrasound-microwave-assisted extraction (UMAE), is a unique approach that combines ultrasound and microwaves as well as the mechanisms of action of both techniques [221]. The plant cell ruptures when strong velocity and energy are applied, releasing more of the desired substances more quickly [35]. Powerful and effective technology with brief extraction times and minimal solvent usage has been described as a way for generating high yields and purity [115]. This combination improves the rate of extraction of bioactive compounds along with boosting the selectivity and decreases the complexity of the extraction process [213]. A unique UMAE technique was developed for the extraction of alkaloids from *Picrasma quassioides*. The extraction yield was researched and improved to determine all the factors that influence it, such as the temperature and duration of the extraction process, the ratio of liquid to solid, and the intensity of the ultrasonic field [213]. They came to the conclusion that choosing the right solvent is crucial for getting the greatest extraction results. The overall extraction yield was also influenced by the extraction yield, solvent/solid ratio, and extraction time. When the following operating parameters were established, the process' efficiency was at its peak: With a liquid to solid ratio of 13:1, an extraction solvent of water and methanol (90:10, v/v) took 21 min to complete. They are referred to as ionic liquid-based ultrasonic-microwave-assisted extraction in the earlier publication (IL-UMAE). *Dioscorea zingiberensis,* who's steroid saponin extraction from it was particularly successful [211]. Utilizing ILs in the extraction and optimising their attributes, such as taking into account the kind of IL, the length of the alkyl chain, and the IL concentration, will increase IL yield. In this investigation, ILs were examined based on the properties of the target molecules. As the IL concentration rises, so does the saponin extraction yield, but as the alkyl chain length lengthens, so does the extraction rate. Even while a modest decrease in yield occurs when the IL content is increased, this could be explained by the solution's higher viscosity, which hinders its capacity to permeate the matrix. After experimenting with a number of different solutions, it was determined that a 0.5 mol/L solution of 1-ethyl-3-methylimidazolium tetrafluoroborate (EMImBF4) in water, microwaved for 500 W for 8 min, with a solvent to material ratio of 15 mL/g and a ratio of extraction time to microwave irradiation of 8 min, provided the best results [211].

2.6.1.3.2. Enzyme-Based–Ultrasound–Microwave-Assisted Extraction (EUMAE)

Integrated extraction techniques are quite uncommon, but this one has just lately been studied, for instance, when scientists were researching the plant *Curculigo orchioides*, which yields oricinol glucoside [118]. The enzyme solution is first incubated with the powdered sample. Cellulase was employed to degrade the plant cell wall, and it was incubated for 10 h at 45 °C. The redissolution in ethanol and water (70:30, v/v) in a solvent to the material ratio of 8 mL/g was chosen as the UMAE extraction process' optimal next step. The extraction process took place at 50 °C for 15 min, with 400 W of irradiation power. The extraction yield was significantly influenced by temperature as well as the length of the extraction, with time being the most crucial element. Hot water extraction, MAE, UAE, or even UMAE have all resulted in poorer yields of the desired chemicals as compared to EUMAE, an enzyme-based ultrasound-microwave-assisted extraction carried out under ideal circumstances [118].

2.7. Therapeutic properties and pharmacological attributes

Haritaki is a natural mild laxative, purgative, astringent, anti-bilious, and potent antioxidant. This fruit is a digestive tonic, expectorant, anti-dysentery, and carminative herb with beneficial effects for stomachic, laxative, asthma, piles, and cough [19, 194]. It contains chemicals that have a positive impact on biological activity and medicinal characteristics. It has a wide range of pharmacological and therapeutic properties, such as antibacterial [96], antifungal [209], antiviral [121], antidiabetic [94], hepatoprotective [198], anti-inflammatory [136], antimutagenic [70], antiprotozoal [16], radioprotective [64], cardioprotective [193], antiarthritic [142], anticaries [170], anticarcinogenic [179], immunomodulatory [55], renoprotective [94], cytoprotective [36], antianaphylactic [185], adaptogenic [185], antiulcerogenic [183], cardioprotective [193], chemopreventive [166], hypolipidemic [130], hypocholesterolemic [85], antispasmodic [128], gastrointestinal motility [197] and wound healing activity [114]. **Table 2.3** summarises the results of pharmacological investigations on haritaki.

Table 2.3. Summary of pharmacological studies on haritaki

Sl. No.	Plant part	Pharmacological activity	Observation	References
1.	Leaves, bark and fruit	Antioxidant and free radical scavenging activity	Aqueous extract of fruit reduced xanthine/xanthine oxidase activity and hemolysis.	Naik et al. [140]; Mahesh et al. [122]
2.	Fruit	Antimutagenic	Hydrolyzable tannins have antimutagenic action against *Salmonella typhimurium.*	Grover and Bala [70]
3.	Fruit	Radioprotective	Reduction in the development of strand breaks in plasmid PBR322 DNA caused by gamma radiation. It also protected human lymphocytes from gamma radiation-induced DNA damage when they were exposed *in vitro*.	Naik et al. [140]; Gandhi and Nair [64]
4.	Fruit	Chemopreventive Activity	Fruit extract demonstrated a chemopreventive effect in male Wistar rats against nickel chloride-induced renal oxidative stress, toxicity, and cell proliferation response.	Prasad et al. [166]
5.	Fruit	Anticarcinogenic activity	Haritaki phenolics have an inhibitory effect on cancer cell proliferation. Chebulinic acid, tannic acid, and ellagic acid were determined to be the main growth inhibiting phenolics.	Saleem et al. [179]
6.	Fruit	Cytoprotective activity	It caused duodenal ulcers to form and appeared to have a cytoprotective effect on the stomach mucosa *in vitro*. T-lymphocyte-mediated cytotoxicity was also inhibited.	Lee et al. [111]; Chang et al. [37]

7.	Fruit	Hepatoprotective activity	Haritaki in an herbal preparation (HP-1) demonstrated hepatoprotective effects in rat hepatocytes when exposed to carbon tetrachloride.	Tasaduq et al. [198]
8.	Fruit and seeds	Antidiabetic and renoprotective activity	Fruit and seeds demonstrated dose-dependent decreases in blood glucose and renoprotective benefits in streptozotocin-induced diabetic rats in both short and long-term experiments.	Kannan et al. [94]; Senthilkumar and Subramanian [181]
9.	Fruit	Antibacterial activity	It was shown to have antibacterial action against a variety of human pathogenic bacteria, including Gram-positive and Gram-negative.	Khan and Jain [96]; Malekzadeh et al. [124]
10.	Fruit	Cardioprotective activity	In isoproterenol-induced cardiac injury in rats, to reduce the effect of isoproterenol on lipid peroxide production and maintain the activities of diagnostic marker enzymes.	Suchalatha and Devi [193]
11.	Fruit and seed	Antiprotozoal activity	Acetone extract of seed has anti-plasmodial action against *Plasmodium falciparum*. Antiamoebic activity against *Entamoeba histolytica* was found to be 89% in rats with experimental caecal amoebiasis.	Bagavan et al. [16]; Sohni et al. [189]
12.	Fruit	Antifungal activity	Antifungal activity was found in an aqueous extract of haritaki against a variety of dermatophytes and yeasts. *In vitro* anticandidal activity of methanol extract against clotrimazole-resistant *Candida albicans* was found.	Vonshak et al. [209]; Dutta et al. [54]; Bonjar [25]

13.	Dried fruit	Anti-inflammatory	Haritaki in a polyherbal formulation (Aller-7) inhibited Freund's adjuvant-induced arthritis in rats in a dose-dependent manner. Inhibits inducible nitric oxide production, making it anti-inflammatory.	Moeslinger et al. [136]
14.	Seed	Anti-arthritic activity	Chebulagic acid derived from immature seeds inhibited the development and progression of collagen-induced arthritis in rats.	Nair et al. [142]
15.	Fruit	Adaptogenic and antianaphylactic activities	Haritaki fruit was one of six ayurvedic herbs given to animals to see whether they were adaptogenic. In animal experiments, blood histamine levels were decreased when fruit extract was given after inducing anaphylactic shock, showing that it has a powerful antianaphylactic effect.	Shin et al. [185]
16.	Fruit	Antiviral activity	On human immunodeficiency virus-1 reverse transcriptase, methanol and aqueous extracts of haritaki demonstrated a strong inhibitory action with $IC_{50} \leq 5$ μg/mL. Haritaki tannins are efficient against potato virus x.	Gambari and Lampronti [63]; Ma et al. [121]
17.	Fruit	Hypolipidemic	Haritaki extract has been shown to have hypolipidemic action against experimentally generated atherosclerosis.	Maruthappan and Shree [130]
18.	Fruit	Hypocholesterolemic acivity	It also has hypocholesterelomic activity in rabbits with hypercholesterolemia and atherosclerosis caused by cholesterol.	Israni et al. [85]

19.	Fruit	Gastrointestinal motility improving	The fruit of haritaki has been proven to speed up gastric emptying. This impact seems to be counterbalanced by a protective effect on the mucosa of the gastrointestinal tract.	Tamhane et al. [197]
20.	Fruit	Antiulcerogenic Activity	Brunner's gland secretory condition improves, which aids in the prevention of duodenal ulcers.	Sharma et al. [183]
21.	Fruit	Antispasmodic activity	Anti-spasmodic effects were proven in one of several investigations by the decrease of aberrant blood pressure and intestinal spasms.	Mard et al. [128]
22.	Fruit	Anticaries activity	Streptococcus mutans adherence was induced by sucrose, and glucan aggregation was produced by glucan. Salivary bacterial count and glycolysis were lowered for up to 90 min after washing with a 10% solution of the extract.	Rai and Joshi [170]; Carounanidy et al. [33]
23.	Leaves	Wound healing activity	Wounds treated with haritaki healed quicker, as evidenced by faster contraction rates and shorter epithelialization times.	Li et al. [114]
24.	Fruit	Immunomodulatory activity	Crude extract induced a cell-mediated immune response in golden hamsters with an amoebic liver abscess.	Dwivedi [55]
25.	Fruit	Anti-allergic activity	In isolated guinea pig ileum substrate, showed significant antiallergic action *in vitro*.	Pratibha et al. [167]
26.	Fruit	Purgative property	An oil fraction from fruit has been shown to have purgative properties.	Vani et al. [204]

Antioxidant compounds, which are provided to human as a dietary components or as specialised preventative medicines, are gaining popularity these days. As a result, antioxidants have become an important element of modern preservation technology and health care. The presence of phenolic chemicals, particularly phenolic acids and flavonoids, is widely recognised to be associated with plants that have antioxidative and pharmacological characteristics. Polyphenols have been proposed by several studies to help in preventing obesity, coronary heart disease, colon cancer, gastrointestinal problems, and diabetes [120, 175]. Polyphenols have capacity to inhibit fatty acid oxidation and give protection against oxidative stress caused by oxidising agents and free radicals [188]. Bioactive compounds extracted from plant extract have been demonstrated in several studies to have a growth inhibitory impact on pathogenic strains [17, 131, 135]. Biological characteristics of polyphenols and health advantages have fuelled research efforts to develop and implement techniques for extracting, separating, and identifying these chemicals from natural sources. These techniques must be thorough, quick, and provide a lot of spectrum data [83]. Haritaki fruit powder has been used to treat chronic diarrhoea and also been used to treat nervous irritation and weakness. Due to its astringent properties, it is used as an adjuvant in haemorrhages and is beneficial for chronic cough, bronchitis, sore throat, and asthma. It also helps with renal calculi, dysuria, urine retention, and skin diseases with discharges such as allergies, urticaria, and other erythematous conditions [11, 205]. Leaves, bark, and fruit of haritaki were found to have strong antioxidant activity, which was attributed to phenolics [36]. Aqueous extract of haritaki reduced xanthine/xanthine oxidase activity and was a good scavenger of DPPH radicals [140]. Free radical induced hemolysis was reduced in a polyherbal formulation (Aller-7/ NR-A2), and nitric oxide release from lipopolysaccharide activated murine macrophages was likewise considerably suppressed [122]. Six extracts and four components from the fruit showed antioxidant activity at different magnitudes of potency [79]. It was shown that methanolic extract may reduce the generation of lipid peroxide and scavenge hydroxyl and superoxide radicals in vitro. The antioxidant activity of aqueous extract was used to assess the prevention of radiation-induced lipid peroxidation in rat liver microsomes at various dosages [109].

2.8. Traditional use of haritaki

The fruit of the haritaki has been used for laxative, carminative, astringent, expectorant, and tonic purposes in Thai traditional medicine. Fever, cough, diarrhoea, gastroenteritis, skin disorders, candidiasis, urinary tract infection, and wound infections are all common maladies treated with it by Tamil Nadu tribes as traditional medicine [45]. It is frequently used as a diuretic and cardiotonic in Ayurvedic formulations [86]. It's utilised to slow down the ageing process and increase lifespan and immunity [2]. It is said to be able to heal blindness and to slow the growth of cancerous tumours [179]. Haritaki is known in Tibetan medicine as a-ru-ra, where 'a' means best of medicines and cures all diseases caused by tridosha (vata, pitta, and kapha, three physiological body elements), 'ru' means the fruit has flesh, bone, and skin, which clears diseases caused by tridosha imbalance, and 'ra' means it has a body like that of a rhinocerous and clears diseases from all dhatus (7 anatomical body constituents). Hariraki is known as the 'King of the Best Medicines,' or 'man-mchog-rgyal-lo' [45].

2.9. Application of haritaki bioactive compounds in pharmaceutical and food industry

Haritaki fruit is widely used as a dietary supplement in Asian and European countries, because of its laxative effects. After meals in south Asian nations, a sweet dish known as Harad ka murabbah (Jam) is traditionally enjoyed. Therapeutic qualities of haritaki have been widely documented, and it is a key component of many Ayurvedic medical formulations [141, 108]. The bioactivity of a particular specific component at a physiologically relevant level at the target location is determined by its concentration. The pharmacokinetic characteristics of a substance have an impact on its preventative or therapeutic effects. Several phenolic substances have well-documented pharmacokinetics [191].

Triphala is an antioxidant, immunomodulator, rejuvenator, anti-aging, analgesic, anti-mutagenic, anti-cancer, anti-microbial, and blood purifier used in Indian ayurvedic medicine. It is made composed of the fruits of three trees: *Terminalia chebula*, *Terminalia bellerica*, and *Embilica officinalis* [140]. Traditionally, Rasayana-based medicines have been used to treat a variety of illnesses that have no pathophysiological connections as determined by modern medicine. *Triphala Rasayana* has a number of therapeutic properties, including antioxidant, anticancer, antidiabetic, antibacterial, immunomodulatory, and anticataract. It is also used as a pillar in the treatment of gastrointestinal diseases, particularly functional gastrointestinal disorders (FGIDs). Due to its easy administration, availability, and low cost, rasayan is becoming more and more popular throughout the world [3].

Natural phenols playing a key role in the prevention of a variety of pathological conditions [68, 203]. Properties such as laxative, antibacterial, cardiotonic, diuretic, hyperlipidemic, and anticancer properties make it useful in medicine [15, 110]. The fruits have anti-fertility properties, making it a possible herbal contraceptive [66]. Polyphenols also have a variety of industrial uses, such as serving as natural colourants and food preservatives. As a result, consuming high-quality foods to offer vital nutritional and bioactive components has become critical to ensuring food security [23, 200].

2.10. Encapsulation

Solids, liquids, or gaseous molecules can be packaged in small, hermetically sealed capsules that release their contents at exact rates under certain conditions using a technique called microencapsulation. The packed materials, often referred to as coated material, core material, actives, internal phase, or payload, may be made up entirely of single ingredients or may contain mixes. According to Desai and Park [49], packaging materials include coating, wall, capsule, membrane, carrier, and shell materials. These substances can be made from sugars, gums, proteins, lipids, gums, natural and modified polysaccharides, and synthetic polymers. Some of the most advanced and cutting-edge encapsulating techniques include fluidized bed coating, spray drying, spray cooling, spray chilling, extrusion, coacervation, liposome entrapment, inclusion complexation, centrifugal suspension separation, lyophilization, cocrystallization, and emulsion. Desai and Park [49] documents that, the widely used microencapsulation technique in the food industry involves altering the physical properties of the original material to make it easier to handle, reducing the reactivity of two ingredients, and protecting the core material from deterioration. Encapsulation's primary goal is to shield the core material from harmful environmental factors, such as the negative effects of light, moisture, and oxygen. This extends the shelf life of the product and encourages the controlled release of the encapsulate [62].

A renewable biopolymer found throughout nature; starch has a wide range of industrial uses. To protect chemicals, starch has been utilised as an encapsulating material, such as vitamins [77, 214], lipids and essential oils [52, 95], flavors [89, 223], drugs [88, 134], pigments [30, 174], polyphenols [47], herbicides [212], proteins [56, 57], microorganisms and probiotics [12, 151], and fragrant compounds [102]. For microencapsulation, numerous botanical sources of both unmodified and modified starches, primarily octenylsuccinate starch, as well as byproducts of its hydrolysis (maltodextrins or dextrans), have been used. Starch has been widely used for microencapsulation due to its wide availability, inexpensive cost, and array of functions. To accomplish the microencapsulation of substances with greater yields, the functionality of starch can be increased or altered via chemical, physical, or enzymatic methods. However, the functioning and physicochemical qualities of the nucleus must still be readily released. The core material is released from the encasing material as a result of pH changes, temperature changes, diffusion brought on by the action of external fluids, chemical reactions, enzymatic hydrolysis, or mechanical breakage [97]. In order to microencapsulate starch, a number of techniques have been documented, including extrusion, freeze drying, spray cooling or spray chilling, coacervation, fluidized-bed coating, and molecular inclusion. However, due to its low cost and adaptability, spray drying is the most used method for microencapsulation since it enables continuous processing while keeping the core material suitably cool until the dry state is attained [144].

The ability of zein, the prolamin portion of corn protein, to coat and encapsulate bioactive substances has long been known [82, 152, 224, 225]. It may be helpful as a medium for encapsulating delicate tastes and bioactive substances. For instance, zein was employed via spray drying, freeze drying, and coacervation procedures to encapsulate flax oil [168], curcumin [67], and cranberry procyanidins [227]. Because of its comparatively large concentration of non-polar amino acids, zein possesses an amphiphilic structure. Due to its structural shape and amphiphilic nature, it can self-assemble.

2.11. Yoghurt

Due to its availability in a variety of forms, including fruit yoghurts, and the health advantages associated with its nutritional composition, live microorganisms, and fermentation process, yoghurt is one of the most popular fermented dairy products. Due to their high antioxidant activity and specific therapeutic characteristics, yoghurt enriched with fruit rich in phenols has especially earned favourable consumer opinion [215]. In addition to its health advantages, yogurt's rheological qualities and texture traits are crucial for sensory evaluation and consumer acceptance. There has been another way for creating yoghurt gel that involves the covalent interaction of phenolic chemicals and proteins [148]. This method is based on protein-phenolic interactions in dairy products

[148, 207]. Phenolic chemicals may engage non-covalently with proteins in the acid gel matrix of yoghurt through hydrophobic interactions, which may then be maintained by hydrogen bonding [38, 207].

2.11.1. Hydrocolloids in yoghurt

According to Nguyen et al. [146], of the four hydrocolloids (gelatin, carrageenan, xanthan, and modified starch) investigated, gelatin appears to be the best stabiliser for skim yoghurt due to its ability to significantly increase product firmness, reduce syneresis and lubricity, and improve sensory perception of skim yoghurt toward full-fat yoghurt. The sample's thickness was increased by modified starch, but it also produced unwanted mouthfeel characteristics like lumpiness and chalkiness. At extremely low dosages, the addition of carrageenan and xanthan gum increased the sample's viscosity and gel strength, but it also increased syneresis and decreased gel stability at high shear rates in tribology measurements. These hydrocolloids also made products chalkier and lumpier, which may have been caused by the casein micelle's loss of flocculation. Baba et al. [14] reported that, guar gum is used to thicken yoghurt after adding walnut and flaxseed oils. 2% concentration of each oil was added independently, along with two different guar gum concentrations (0.025% and 0.05%). Samples of fortified yoghurt were examined for their microbiological, antioxidant, rheological, and functional qualities. Additionally determined were the product's oxidative shelf-life and fatty acid profile. Yogurts with added oil produced more syneresis, antioxidant activity, and malondialdehyde while having a lower bacteria count. Gum addition had no significant ($p>0.05$) impact on the microbiological content but considerably ($p>0.05$) decreased pH, syneresis, and boosted oxidative stability and antioxidant activity of yoghurt samples. Each and every sample of yoghurt displayed pseudoplastic flow behaviour with yield stress that grew as gum and oil concentrations increased. The G′, G″, and composite viscosity of yoghurt samples were raised by adding gum and oil.

The MUFA and PUFA levels of the walnut-fortified yoghurt samples were substantially greater than those of the other samples. In comparison to flaxseed oil fortification, walnut oil fortification showed greater sensory indices and improved overall quality features. Therefore, when adding essential fatty acids to yoghurt, walnut oil is preferred to flaxseed oil. A concentration-dependent pH decrease was brought on by the addition of gum. According to Perina et al. [158], adding a vegetable oil emulsion considerably changed the pH of yoghurts. All samples, including the control, saw a pH reduction during the course of the 15-day storage period. A 30-day storage period caused yoghurt's pH to fluctuate from 4.45 to 4.30, as previously reported by Chaikham, [34]. Previous studies using guar gum [113] and essential oils [216] added to yoghurt samples over periods of 15 and 21 days, respectively, found that the pH of the samples decreased. According to Goyal et al. [69] and Estrada Andino [58], the syneresis of yoghurt samples containing microencapsulated flaxseed oil and EPA-rich fish oils increased by 7.4–7.6% and 7.5%, respectively. Gum was added in a concentration of 0.025%, which significantly reduced syneresis.

Yogurt gel’s inter-aggregate bonds may be strengthened by guar gum, while casein micelles reduced molecular mobility may prevent phase separation [59, 159]. Previous studies have shown that adding hydrocolloids such starch, guar gum, xanthan gum, and gelation causes syneresis to decrease [59, 65, 100]. According to Kiros et al. [100], gelatin syneresis was decreased at 0.25% but dramatically elevated at 0.5% level of supplementation. According to Everett and McLeod [59], depletion flocculation is the cause of higher syneresis with increasing guar gum concentration. The tendency of guar gum to demix at higher guar gum concentrations due to its poor compatibility with sodium caseinate may also exacerbate the syneresis of yoghurt [145]. Additionally, guar gum-containing yoghurt samples showed a rise in G′ and G″ values in a concentration-dependent manner [113]. This change that was noticed with the inclusion of guar gum may be explained by how the casein matrix of yoghurt interacts with hydrocolloid to reinforce the three-dimensional network [28]. Everett and McLeod [59] also noted that increasing guar gum concentration to depletion flocculation increased the compactness of casein micellar aggregates (greater dynamic moduli). Additionally, Peker and Arslan [156] noted a non-significant change in the TPC of yoghurt samples when locust bean gum concentration increased. Quercetin [101] and lysozyme [73] have both been shown to have increased DPPH radicle scavenging activity when combined with guar gum. According to reports, adding locust gum to yoghurt samples increased their antioxidant activity [156].

Acharjee et al. [1] reported orange juice extraction left behind pomace, which was dried at 70 °C. The pomace powder was added to yoghurt at three different concentrations 1%, 2%, and 3 % to enrich it. The yoghurt samples' physical, chemical, and sensory characteristics were assessed while being stored in the refrigerator and contrasted with a control sample. With higher pomace powder concentrations and longer storage times, the acidity also increased. The level of enrichment was discovered to increase syneresis, which was found to be lower in the enriched samples than in the control samples. Syneresis diminished while being stored, then rose as time went on. It was discovered that firmness decreased with enrichment level and storage time. With each level of enrichment, the consistency index rose; however, during storage, it first rose and then fell. Sensory tests revealed that panellists liked yoghurt that had 1% pomace powder added to it [1].

2.11.2. Encapsulated phenolic compounds in yoghurt

Yogurt is a fermented dairy product that is widely consumed, which has created the possibility for developing a new concept for it as a highly valuable functional food item. Hamid et al. [74] reported that yogurt was enhanced using lyophilized microencapsulated phenolic extract powder (MPE) from the peel of wild pomegranate fruit. Based on sensory qualities, the treatment supplemented with 2% MPE was chosen as the best among the other treatments. After the addition of 2% MPE, yoghurt bioactive components and different antioxidant characteristics showed a substantial increase ($p > 0.05$). Various features' changes were noted at various storage intervals (0, 7 and 14 days). Enhanced yoghurt maintained higher levels of phenolics, flavonoids, radical scavenging activity, metal chelating activity, FRAP, and reducing power after 14 days of storage in addition to higher colour ratings and sensory appeal. Therefore, yoghurt could be stored safely in polystyrene cups for 14 days at a refrigerated temperature (4-7 °C) with little modification to its quality characteristics. This study reveals that MPE enrichment without sensory changes, with maximal retention of bioactive components, can considerably improve the functional and antioxidant qualities of yoghurt. As a result, product might be used commercially. Additionally, the study found that enhanced yoghurt had increased phenolic levels and antioxidant activity, which may pave the door for novel ways to consume functional foods.

Silva et al. [187] reported that Guarana seed extract (GSE) and *Lacticaseibacillus paracasei* BGP-1 co-effects encapsulations on the bacteria's viability and the stability of phenolic components during microcapsule storage and after their use in yoghurt-based beverages were investigated. The co-encapsulation of the putative probiotic and GSE increased the survivability of *L. paracasei* BGP-1 during storage while protecting the phenolic compounds, with ultimate retention of about 88%. In relation to the yoghurt compositions, microencapsulation prevented post-fermentation and disguised the bitter taste of the GSE. As a result, yoghurt containing microcapsules was often more acceptable than yoghurt containing free GSE. Additionally, GSE's encapsulation and association allowed *L. paracasei* counts to remain constant in yoghurt formulations held at 7 °C for up to 28 days, at roughly 7 log cfu g^{-1}. Co-encapsulation, thus, is an important strategy for the use and defence of beneficial compounds in yoghurt drinks.

dos Santos et al. [53] reported that anthocyanins are abundant in blackberry fruit, but depending on how it is processed, its stability may be reduced. In this work, the bioavailability of anthocyanins in yoghurt that had been treated with blackberry pomace microcapsules and in yoghurt that had been incubated with the microcapsules following in vitro digestion were assessed. The resilience of blackberry pomace microcapsules to light and light-free conditions was also evaluated. The three microencapsulation methods-spray-drying, freeze-drying, and ionic gelation-all generated satisfactory yields (above 53%) and encapsulation efficiencies (above 95%). Ionic gelation and spray-drying approaches produced microcapsules that were more stable in the presence and absence of light than the freeze-drying technique did. Cyanidin-3-glucoside bioavailability was better when spray-dried microcapsules were introduced to yoghurt compositions than when freeze-dried and ionic gelated microcapsules were. Because the yoghurt formulations demonstrated improved post-gastrointestinal digestion bioavailability than the pure microcapsules, the food industry may be able to employ blackberry microcapsules to generate high-value goods. Seregelj et al. [182] reported that, fortified with bioactive components such as carotenoids. In this way, regular diets can lessen both the problem of accumulation of food by-products that are rich in bioactive components and the disorders linked to nutritional deficiencies. In this study, following extensive analysis and the extraction of carotenoids from carrot waste (CW), the encapsulating procedure was carried out by electrostatic extrusion. Two concentrations of fully described CW beads (2.5 and 5 g/100g) were added to the yoghurt during the last step of production. Yoghurts that were both unfortified and fortified underwent comparative investigations during a 28 days storage period at 4 °C. A portion of the daily required intake of carotene is provided by yoghurt fortification with both amounts. Overall, the fortified yoghurts physico-chemical and microbiological qualities were stable during storage. The encapsulated carotenoids significantly increased the yogurt's antioxidant activity, allowing for the creation of fortified yoghurt with excellent nutritional value [182].

2.12. Conclusion

Traditional Indian medicine systems such as Siddha, Ayurveda, and Unani rely heavily on medicinal plants to treat illnesses. Herbal therapies are constantly gaining in popularity across the world due to the fact that they are safe and natural solutions. Many more researchers have devoted themselves to further study of medicinal plants as a result of extensive investigation. Haritaki is a multipurpose plant that has a wide spectrum of pharmacological and medicinal characteristics. This versatile medicinal plant is a one-of-a-kind source of a wide range of chemicals with different chemical structures. It is a significant herbal medicine that is used to treat a variety of illnesses, including cancer. Given its remarkable qualities and chemical makeup, additional pharmacological research is still needed to fully understand how fruit can be used as food additives, safety measures, and nutraceuticals. Calculated fruit engineering qualities will be used in designing equipment for the fruits, such as hoppers, chutes, sorters, and grading machines.

In order to develop equipment for the fruits, such as hoppers, chutes, sorters, and grading machines, engineering properties of the fruits were estimated. The engineering properties are helpful in providing academics and enterprises with comprehensive knowledge for fruit post-harvest activities. On an industrial scale, it is possible to sort and grade fruit according to its bulk, which will be more cost-effective, less labor-intensive, and time-saving. In conclusion, the physical characteristics of the fruits and their mass model contribute to knowledge growth and impart useful information for handling, storing, and other industrial unit operations after harvest.

Compared to conventional and unconventional extraction methods, new technology-assisted extractions produce a greater amount of bioactive compounds. Combining cutting-edge technology could facilitate the development of more biologically active extraction methods. There are many benefits, including speed, comfort, and safety. It is possible to extract heat-sensitive compounds (and solvent ratios). These characteristics lead to high extraction yields and high-quality extracts (with a high concentration of interest compounds). Generally speaking, these techniques may extract caffeine, flavonoids, carotenoids, phenolic compounds, and a range of other advantageous elements.

2.13. References

1. Acharjee, A., Afrin, S. M., and Sit, N. Physicochemical, textural, and rheological properties of yoghurt enriched with orange pomace powder. *Journal of Food Processing and Preservation*, 45(2), 2021.
2. Aher, V., and Wahi, A. Immunomodulatory activity of alcohol extract of *Terminalia chebula retz.* combretaceae. *Tropical Journal of Pharmaceutical Research*, 10(5), 567-575, 2011.
3. Ahmed, S., Ding, X., and Sharma, A. Exploring scientific validation of Triphala Rasayana in ayurveda as a source of rejuvenation for contemporary healthcare: An update. *Journal of Ethnopharmacology*, 273, 113829, 2021.
4. Aiyer, H. S., Srinivasan, C., and Gupta, R. C. Dietary berries and ellagic acid diminish estrogen-mediated mammary tumorigenesis∈ ACI rats. *Nutrition and Cancer,* 60(2), 227-234, 2008.
5. Akbolat, D. A. V. U. T., Ertekin, C., Menges, H. O., Ekinci, K. A. M. İ. L., and Erdal, I. Physical and nutritional properties of jujube (Zizyphus jujuba Mill.) growing in Turkey. *Asian Journal of Chemistry*, 20(1), 757, 2008.
6. Alasalvar, C., Grigor, J. M., Zhang, D., Quantick, P. C., and Shahidi, F. Comparison of volatiles, phenolics, sugars, antioxidant vitamins, and sensory quality of different colored carrot varieties. *Journal of Agricultural and Food Chemistry*, 49(3), 1410-1416, 2001.
7. Altuntas, E., and Demirtola, H. Effect of moisture content on physical properties of some grain legume seeds. *New Zealand Journal of Crop and Horticultural Science*, 35(4), 423-433, 2007.
8. Altuntas, E., and Özkan, Y. Physical and mechanical properties of some walnut (Juglans regia L.) cultivars. International Journal of Food Engineering, 4(4), 1556–3758, 2008.
9. Alvarez, A., Poejo, J., Matias, A. A., Duarte, C. M., Cocero, M. J., and Mato, R. B. Microwave pretreatment to improve extraction efficiency and polyphenol extract richness from grape pomace. Effect on antioxidant bioactivity. *Food and Bioproducts Processing*, 106, 162-170, 2017.
10. Andrade, R. D., Lemus, R., and Perez, C. E. Models of sorption isotherms for food: uses and limitations. *Vitae*, 18(3), 325-334, 2011.

11. Aslokar, L., Kakkar, K. K., and Chakre, O. J. Supplement to Glossary of Indian Medicinal Plants with Active Principles. *Directorate CSIR, New Delhi, India*, 291-293, 1992.
12. Avila-Reyes, S. V., Garcia-Suarez, F. J., Jiménez, M. T., San Martín-Gonzalez, M. F., and Bello-Perez, L. A. Protection of L. *rhamnosus* by spray-drying using two prebiotics colloids to enhance the viability. *Carbohydrate polymers*, 102, 423-430, 2014.
13. Aydin, C. Physical properties of almond nut and kernel. *Journal of food engineering*, 60(3), 315-320, 2003.
14. Baba, W. N., Jan, K., Punoo, H. A., Wani, T. A., Dar, M. M., and Masoodi, F. A. Techno-functional properties of yoghurts fortified with walnut and flaxseed oil emulsions in guar gum. *LWT*, 92, 242-249, 2018.
15. Bag, A., Bhattacharyya, S. K., Pal, N. K., and Chattopadhyay, R. R. In vitro antimicrobial potential of *Terminalia chebula* fruit extracts against multidrug–resistant uropathogens. *Asian Pacific Journal of Tropical Biomedicine*, 2(3), S1883-S1887, 2012.
16. Bagavan, A., Rahuman, A. A., Kamaraj, C., Kaushik, N. K., Mohanakrishnan, D., and Sahal, D. Antiplasmodial activity of botanical extracts against *Plasmodium falciparum*. *Parasitology Research*, 108(5), 1099-1109, 2011.
17. Balasaraswathi, R., Sadasivam, S., Ward, M., and Walker, J. M. An antiviral protein from Bougainvillea spectabilis roots; purification and characterisation. *Phytochemistry*, 47(8), 1561-1565, 1998.
18. Balasundram, N., Sundram, K., and Samman, S. Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food Chemistry*, 99(1), 191-203, 2006.
19. Barthakur, N. N., and Arnold, N. P. Nutritive value of the chebulic myrobalan (Terminalia chebula Retz.) and its potential as a food source. *Food chemistry*, 40(2), 213-219, 1991.
20. Bart-Plange, A., Mohammed-Kamil, A. P., Addo, A., and Teye, E. Some physical and mechanical properties of cashew nut and kernel grown in Ghana. *International Journal of Science and nature*, 3(2), 406-415, 2012.
21. Beecher, G. R. Overview of dietary flavonoids: nomenclature, occurrence and intake. *The Journal of Nutrition*, 133(10), 3248S-3254S, 2003.

22. Bezerra, C. V., Amante, E. R., de Oliveira, D. C., Rodrigues, A. M., and da Silva, L. H. M. Green banana (*Musa cavendishii*) flour obtained in spouted bed–Effect of drying on physico-chemical, functional and morphological characteristics of the starch. *Industrial crops and products*, 41, 241-249, 2013.
23. Bharucha, Z., and Pretty, J. The roles and values of wild foods in agricultural systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1554), 2913-2926, 2010.
24. Bodet, C., Grenier, D., Chandad, F., Ofek, I., Steinberg, D., and Weiss, E. I. Potential oral health benefits of cranberry. *Critical Reviews in Food Science and Nutrition*, 48(7), 672-680, 2008.
25. Bonjar, G. S. Inhibition of Clotrimazole-resistant *Candida albicans* by plants used in Iranian folkloric medicine. *Fitoterapia*, 75(1), 74-76, 2004.
26. Boyadzhiev, L., Dimitrov, K., and Metcheva, D. Integration of solvent extraction and liquid membrane separation: an efficient tool for recovery of bio-active substances from botanicals. *Chemical Engineering Science*, 61(12), 4126-4128, 2006.
27. Bravo, L. Polyphenols: chemistry, dietary sources, metabolism, and nutritional significance. *Nutrition Reviews*, 56(11), 317-333, 1998.
28. Bruzzone, F., Ares, G., and Giménez, A. Temporal aspects of yoghurt texture perception. *International Dairy Journal*, 29(2), 124-134, 2013.
29. Burubai, W., Akor, A. J., Igoni, A. H., and Puyate, Y. T. Some physical properties of African nutmeg (*Monodora myristica*). *International Agrophysics*, *21*(2), 2007.
30. Cai, Y. Z., and Corke, H. Production and properties of spray-dried Amaranthus betacyanin pigments. *Journal of food science*, 65(7), 1248-1252, 2000.
31. Carbone, E. T., Kass, P. H., and Evans, K. D. Feasibility of using rice hulls as bedding for laboratory mice. *Journal of the American Association for Laboratory Animal Science*, 55(3), 268-276, 2016.
32. Caridi, D., Trenerry, V. C., Rochfort, S., Duong, S., Laugher, D., and Jones, R. Profiling and quantifying quercetin glucosides in onion (*Allium cepa L.*) varieties using capillary zone electrophoresis and high performance liquid chromatography. *Food Chemistry*, 105(2), 691-699, 2007.
33. Carounanidy, U., Satyanarayanan, R., and Velmurugan, A. Use of an aqueous extract of *Terminalia chebula* as an anticaries agent: a clinical study. *Indian Journal of Dental Research*, 18(4), 152-156, 2007.

34. Chaikham, P. Stability of probiotics encapsulated with Thai herbal extracts in fruit juices and yoghurt during refrigerated storage. *Food Bioscience*, 12, 61-66, 2015.
35. Chan, C. H., Yusoff, R., Ngoh, G. C., and Kung, F. W. L. Microwave-assisted extractions of active ingredients from plants. *Journal of Chromatography A*, 1218(37), 6213-6225, 2011.
36. Chang, C. L., and Lin, C. S. Development of antioxidant activity and pattern recognition of *Terminalia chebula Retzius* extracts and its fermented products, Research Institute of Biotechnology, Hungkuang University, (61), 115-129, 2010.
37. Chang, C. L., Lin, C. S., Lai, G. H., Chen, Y. H., Tuan, W. C., and Hsu, C. M. Influence of *Terminalia chebula* extracts on the effect of PC12 cell growth. *Journal of Traditional Medicines*, 21(1), 23-30, 2010.
38. Charlton, A. J., Baxter, N. J., Khan, M. L., Moir, A. J., Haslam, E., Davies, A. P., and Williamson, M. P. Polyphenol/peptide binding and precipitation. *Journal of Agricultural and Food Chemistry*, 50(6), 1593-1601, 2002.
39. Chattopadhyay, R. R., and Bhattacharyya, S. K. Plant Review. Terminalia chebula: An update. *Pharmacognosy Reviews*, 1: 151-157, 2007.
40. Chen, X., Sun, F., Ma, L., Wang, J., Qin, H., and Du, G. In vitro evaluation on the antioxidant capacity of triethylchebulate, an aglycone from *Terminalia chebula Retz* fruit. *Indian Journal of Pharmacology*, 43(3), 320, 2011.
41. Chisté, R. C., Silva, P. A., Lopes, A. S., and da Silva Pena, R. Sorption isotherms of tapioca flour. *International Journal of Food Science & Technology*, 47(4), 870-874, 2012.
42. Cook, N. C., and Samman, S. Flavonoids—chemistry, metabolism, cardioprotective effects, and dietary sources. *The Journal of Nutritional Biochemistry*, 7(2), 66-76, 1996.
43. D Archivio, M., Filesi, C., Di Benedetto, R., Gargiulo, R., Giovannini, C., and Masella, R. Polyphenols, dietary sources and bioavailability. *Annali-Istituto Superiore di Sanita*, 43(4), 348, 2007.
44. Dash, A. K., Pradhan, R. C., Das, L. M., and Naik, S. N. Some physical properties of simarouba fruit and kernel. *International Agrophysics*, 22(1), 111-116, 2008.
45. Dash, V. B., and Tulku, V. D. Positive Health in Tibetan Medicine. Sri Satguru Publications, (p. 115), 1991.

46. De Castro, M. L., and Garcıa-Ayuso, L. E. Soxhlet extraction of solid materials: an outdated technique with a promising innovative future. *Analytica Chimica Acta*, 369(1-2), 1-10, 1998.
47. Deladino, L., Teixeira, A.S., Navarro, A.S., Alvarez, I., Molina-García, A.D., and Martino, M. Corn starch systems as carriers for yerba mate (*Ilex paraguariensis*) antioxidants. *Food Bioprod. Process*, 94, 463-472, 2015.
48. Delprete, C., and Sesana, R. Mechanical characterization of kernel and shell of hazelnuts: Proposal of an experimental procedure. *Journal of Food Engineering*, 124, 28-34, 2014.
49. Desai, K. G. H., and Hyun J. P. Recent developments in microencapsulation of food ingredients. *Drying Technology*, 23(7), 1361-1394, 2005.
50. Dixit, D., Dixit, A. K., Lad, H., Gupta, D., and Bhatnagar, D. Radioprotective effect of *Terminalia Chebula Retzius* extract against γ-irradiation-induced oxidative stress. *Biomedicine & Aging Pathology*, 3(2), 83-88, 2013.
51. Dodke, P. C., and Pansare, T. A. Ayurvedic and modern aspect of Terminalia chebula Retz. Haritaki an overview. *International Journal of Ayurvedic and Herbal Medicine*, 7(2), 2508-17, 2017.
52. Domian, E., Brynda-Kopytowska, A., Cenkier, J., and Świrydow, E. Selected properties of microencapsulated oil powders with commercial preparations of maize OSA starch and trehalose. *Journal of Food Engineering*, 152, 72-84, 2015.
53. dos Santos, S. S., Paraíso, C. M., Romanini, E. B., Correa, V. G., Peralta, R. M., da Costa, S. C., and Madrona, G. S. Bioavailability of blackberry pomace microcapsules by using different techniques: An approach for yogurt application. *Innovative Food Science & Emerging Technologies*, 81, 103111, 2022.
54. Dutta, B. K., Rahman, I., and Das, T. Antifungal activity of Indian plant extracts Antimyzetische Aktivität indischer Pflanzenextrakte. *Mycoses*, 41(11/12), 535-536, 1998.
55. Dwivedi, S. Anthelmintic activity of alcoholic and aqueous extract of fruits of *Terminalia chebula Retz*. *Ethnobotanical Leaflets*, 12: 741-743, 2008.
56. Elfstrand, L., Eliasson, A. C., and Wahlgren, M. The effect of starch material, encapsulated protein and production conditions on the protein release from starch microspheres. *Journal of pharmaceutical sciences*, 98(10), 3802-3815, 2009.

57. Elfstrand, L., Eliasson, A. C., Jönsson, M., Reslow, M., and Wahlgren, M. From starch to starch microspheres: Factors controlling the microspheres quality. *Starch-Stärke*, 58(8), 381-390, 2006.
58. Estrada Andino, J. D. Production and processing of a functional yogurt fortified with microencapsulated omega-3 and vitamin E, 2011.
59. Everett, D. W., and McLeod, R. E. Interactions of polysaccharide stabilisers with casein aggregates in stirred skim-milk yoghurt. *International Dairy Journal*, 15(11), 1175-1183, 2005.
60. Farahnaky, A., Mansoori, N., Majzoobi, M., and Badii, F. Physicochemical and sorption isotherm properties of date syrup powder: Antiplasticizing effect of maltodextrin. *Food and bioproducts processing*, 98, 133-141, 2016.
61. Farnsworth, N. R., Akerele, O., Bingel, A. S., Soejarto, D. D., and Guo, Z. Medicinal plants in therapy. *Bulletin of the World Health Organization*, 63(6), 965, 1985.
62. F-Gibbs, S. K., Inteaz. A., and Catherine, M. B. Encapsulation in the food industry: a review. *International Journal of Food Sciences and Nutrition*, 50(3), 213-224, 1999.
63. Gambari, R., and Lampronti, I. Inhibition of immunodeficiency type-1 virus (HIV-1) life cycle by medicinal plant extracts and plant-derived compounds. *Advances in Phytomedicine*, 2, 299-311, 2006.
64. Gandhi, N. M., and Nair, C. K. K. Radiation protection by *Terminalia chebula*: some mechanistic aspects. *Molecular and Cellular Biochemistry*, 277(1), 43-48, 2005.
65. Gentès, M. C., Turgeon, S. L., and St-Gelais, D. Impact of starch and exopolysaccharide-producing lactic acid bacteria on the properties of set and stirred yoghurts. *International Dairy Journal*, 55, 79-86, 2016.
66. Ghosh, A., Jana, K., Pakhira, B. P., Tripathy, A., and Ghosh, D. (2015). Anti-fertility effect of aqueous-ethanolic (1: 1) extract of the fruit of *Terminalia chebula*: Rising approach towards herbal contraception. *Asian Pacific Journal of Reproduction*, 4(3), 201-207, 2015.
67. Gómez-Estaca, J., Balaguer, M. P., Gavara, R., and Hernandez-Munoz, P. Formation of zein nanoparticles by electrohydrodynamic atomization: Effect of the main processing variables and suitability for encapsulating the food coloring and active ingredient curcumin. *Food Hydrocolloids*, 28(1), 82-91, 2012.
68. Gordon, M. H. Dietary antioxidants in disease prevention. *Natural Product Reports*, 13(4), 265-273, 1996.

69. Goyal, A., Sharma, V., Sihag, M. K., Singh, A. K., Arora, S., and Sabikhi, L. Fortification of dahi (Indian yoghurt) with omega-3 fatty acids using microencapsulated flaxseed oil microcapsules. *Journal of food science and technology*, 53(5), 2422-2433, 2016.
70. Grover, I. S., and Bala, S. A. R. O. J. Antimutagenic activity of *Terminalia chebula* (myroblan) in *Salmonella typhimurium*. *Indian Journal of Experimental Biology*, 30(4), 339-341, 1992.
71. Gupta, P. C. Biological and pharmacological properties of Terminalia chebula Retz.(Haritaki)-An overview. *Int J pharm pharm Sci*, 4(3), 62-68, 2012.
72. Hagerman, A. Tannin handbook, 2002.
73. Hamdani, A. M., Wani, I. A., Bhat, N. A., and Siddiqi, R. A. Effect of guar gum conjugation on functional, antioxidant and antimicrobial activity of egg white lysozyme. *Food Chemistry*, 240, 1201-1209, 2018.
74. Hamid, H., Thakur, N. S., Rana, N., and Thakur, A. Effect of Different Solvents on Extraction of Phenolic Antioxidants by Reflux Method from Wild Pomegranate Flavedo, their Antioxidant and Antibacterial Properties. *Indian Journal of Pharmaceutical Sciences*, 84(4), 838-847, 2022.
75. Handa, S. S. An overview of extraction techniques for medicinal and aromatic plants. *Extraction Technologies for Medicinal and Aromatic Plants*, 1, 2008.
76. Harborne, J. B., Baxter, H., and Moss, G. P. Pythochemical Dictionary: A Handbook of Bioactive Compounds from Plants. *Taylor and Fransic Ltd*, 1999.
77. Hategekimana, J., Masamba, K. G., Ma, J., and Zhong, F. Encapsulation of vitamin E: Effect of physicochemical properties of wall material on retention and stability. *Carbohydrate Polymers*, 124, 172-179, 2015.
78. Hayoglu, I., and Faruk Gamli, O. Water sorption isotherms of pistachio nut paste. *International journal of food science & technology*, 42(2), 224-227, 2007.
79. Hazra, B., Sarkar, R., Biswas, S., and Mandal, N. Comparative study of the antioxidant and reactive oxygen species scavenging properties in the extracts of the fruits of *Terminalia chebula*, *Terminalia belerica* and *Emblica officinalis*. *BMC Complementary and Alternative Medicine*, 10(1), 1-15, 2010.
80. Hollman, P. H., and Katan, M. B. Dietary flavonoids: intake, health effects and bioavailability. *Food and Chemical Toxicology*, 37(9-10), 937-942, 1999.

81. Huie, C. W. A review of modern sample-preparation techniques for the extraction and analysis of medicinal plants. *Analytical and Bioanalytical Chemistry*, 373(1), 23-30, 2002.
82. Hurtado-López, P., and Murdan, S. Zein microspheres as drug/antigen carriers: A study of their degradation and erosion, in the presence and absence of enzymes. *Journal of microencapsulation*, 23(3), 303-314, 2006.
83. Ignat, I., Volf, I., and Popa, V. I. A critical review of methods for characterisation of polyphenolic compounds in fruits and vegetables. *Food Chemistry*, 126(4), 1821-1835, 2011.
84. Iguedjtal, T., Louka, N., and Allaf, K. Sorption isotherms of potato slices dried and texturized by controlled sudden decompression. *Journal of Food Engineering*, 85(2), 180-190, 2008.
85. Israni, D. A., Patel, K. V., and Gandhi, T. R. Anti-hyperlipidemic activity of aqueous extract of *Terminalia chebula* & Gaumutra in high cholesterol diet fed rats. *Pharma Science Monitor*, 1(1), 48-59, 2010.
86. Jagtap, A. G., and Karkera, S. G. Potential of the aqueous extract of *Terminalia chebula* as an anticaries agent. *Journal of Ethnopharmacology*, 68(1-3), 299-306, 1999.
87. Jambrak, A. R., Mason, T. J., Paniwnyk, L., and Lelas, V. Accelerated drying of button mushrooms, Brussels sprouts and cauliflower by applying power ultrasound and its rehydration properties. *Journal of Food Engineering*, 81(1), 88-97, 2007.
88. Janaswamy, S. Encapsulation altered starch digestion: Toward developing starch-based delivery systems. *Carbohydrate polymers*, 101, 600-605, 2014.
89. Jeon, Y. J., Vasanthan, T., Temelli, F., and Song, B. K. The suitability of barley and corn starches in their native and chemically modified forms for volatile meat flavor encapsulation. *Food Research International*, 36(4), 349-355, 2003.
90. Jha, A. K., and Sit, N. Comparison of response surface methodology (RSM) and artificial neural network (ANN) modelling for supercritical fluid extraction of phytochemicals from Terminalia chebula pulp and optimization using RSM coupled with desirability function (DF) and genetic algorithm (GA) and ANN with GA. *Industrial Crops and Products*, 170, 113769, 2021.
91. Juang, L. J., Sheu, S. J., and Lin, T. C. Determination of hydrolyzable tannins in the fruit of *Terminalia chebula Retz*. by high-performance liquid chromatography and capillary electrophoresis. *Journal of Separation Science*, 27(9), 718-724, 2004.

92. Kaleemullah, S., and Gunasekar, J. J. Postharvest Technology: Moisture-dependent physical properties of Arecanut kernels. *Biosystems engineering*, 82(3), 331-338, 2002.
93. Kamil Hussain, M., Saquib, M., and Faheem Khan, M. Techniques for Extraction, Isolation, and Standardization of Bio-active Compounds from Medicinal Plants. In *Natural Bio-Active Compounds* (pp. 179-200). Springer, Singapore, 2019.
94. Kannan, V. R., Rajasekar, G. S., Rajesh, P., Balasubramanian, V., Ramesh, N., Solomon, E. K., and Chandru, S. Anti-diabetic Activity on Ethanolic Extracts of Fruits of. *American Journal of Drug Discovery and Development*, 2(3), 135-42, 2012.
95. Kapuśniak, J., and Tomasik, P. Lipid microencapsulation in starch. *Journal of microencapsulation*, *23*(3), 341-348, 2006.
96. Khan, K. H., and Jain, S. K. Regular intake of *Terminalia chebula* can reduce the risk of getting typhoid fever. *Advanced Biotech*, 8(9), 10-15, 2009.
97. Khan, P. F. K. A., Rohit, P., Pave, A. C., Sanap, M. D., Guajarati, N. A., Rane, B. R., and Pawar, S. P. A Review on microencapsulation. *Pharma Science Monitor*, 6(2), 2015.
98. Khawas, P., and Deka, S. C. Moisture sorption isotherm of underutilized culinary banana flour and its antioxidant stability during storage. *Journal of Food Processing and Preservation*, 41(4), 2017.
99. Kim, A. N., Kim, H. J., Chun, J., Heo, H. J., Kerr, W. L., and Choi, S. G. Degradation kinetics of phenolic content and antioxidant activity of hardy kiwifruit (*Actinidia arguta*) puree at different storage temperatures. *LWT*, 89, 535-541, 2018.
100. Kiros, E., Seifu, E., Bultosa, G., and Solomon, W. K. Effect of carrot juice and stabilizer on the physicochemical and microbiological properties of yoghurt. *LWT-Food Science and Technology*, 69, 191-196, 2016.
101. Kopjar, M., Lončarić, A., and Pichler, A. Influence of disaccharides and pectin addition on antioxidant activity of phenolic. *Journal of Nutrition & Food Sciences*, 6(7), 2016.
102. Korus, J., Tomasik, P., and Lii, C. Y. Microcapsules from starch granules. *Journal of microencapsulation*, 20(1), 47-56, 2003.
103. Kumar, A. A review of traditional anticancer nano-medicine: Triphala. *The Pharma Innovation*, 3(7, Part B), 60, 2014.
104. Kumar, A., Kandasamy, P., Chakraborty, I., and Hangshing, L. Analysis of energy consumption, heat and mass transfer, drying kinetics and effective moisture

diffusivity during foam-mat drying of mango in a convective hot-air dryer. *Biosystems Engineering*, 219, 85-102, 2022.

105. Kumar, A., Lakshman, K., Jayaveera, K. N., Tripathi, S. M., and Satish, K. V. Estimation of gallic acid, rutin and quercetin in *Terminalia chebula* by HPTLC. *Jordan Journal Pharmaceutical Sciences*, 3(1), 63-68, 2010.

106. Kumar, B. S., Lakshman, K., Jayaveera, K. N., Krishna, N. V., Manjunath, M., Suresh, M. V., and Naik, S. Estimation of rutin and quercetin in Terminalia chebula by HPLC. *Asian Journal of Research in Chemistry*, 2(4), 388-389, 2009.

107. Kumar, S., Pradhan, R. C., and Mishra, S. Exploration of Shorea robusta (Sal) seeds, kernels and its oil. *Cogent Food & Agriculture*, 2(1), 1186140, 2016.

108. Lata, H., Chandra, S., Techen, N., Khan, I. A., and ElSohly, M. A. Molecular Analysis of Genetic Stability of Micropropagated Plants of *Cannabis sativa* L. using ISSR Markers. *Planta Medica*, 75(04), P-6, 2009.

109. Lee, B. W., Lee, J. H., Lee, S. T., Lee, H. S., Lee, W. S., Jeong, T. S., and Park, K. H. Antioxidant and cytotoxic activities of xanthones from Cudrania tricuspidata. *Bioorganic & Medicinal Chemistry Letters*, 15(24), 5548-5552, 2005.

110. Lee, H. S., Jung, S. H., Yun, B. S., and Lee, K. W. Isolation of chebulic acid from *Terminalia chebula Retz*. and its antioxidant effect in isolated rat hepatocytes. *Archives of Toxicology*, 81(3), 211-218, 2007.

111. Lee, H. S., Koo, Y. C., Suh, H. J., Kim, K. Y., and Lee, K. W. Preventive effects of chebulic acid isolated from *Terminalia chebula* on advanced glycation endproduct-induced endothelial cell dysfunction. *Journal of Ethnopharmacology*, 131(3), 567-574, 2010.

112. Lee, J. O., Park, M. H., Choi, Y. H., Ha, Y. L., and Ryu, C. H. New fermentation technique for complete digestion of soybean protein. *Journal of Microbiology and Biotechnology*, 17(11), 1904-1907, 2007.

113. Lee, Y., and Chang, Y. H. Influence of guar gum addition on physicochemical, microbial, rheological and sensory properties of stirred yoghurt. *International Journal of Dairy Technology*, 69(3), 356-363, 2016.

114. Li, K., Diao, Y., Zhang, H., Wang, S., Zhang, Z., Yu, B., and Yang, H. Tannin extracts from immature fruits of *Terminalia chebula Fructus Retz*. promote cutaneous wound healing in rats. *BMC Complementary and Alternative Medicine*, 11(1), 1-9, 2011.

115. Lianfu, Z., and Zelong, L. Optimization and comparison of ultrasound/microwave assisted extraction (UMAE) and ultrasonic assisted extraction (UAE) of lycopene from tomatoes. *Ultrasonics Sonochemistry*, 15(5), 731-737, 2008.
116. Lie, H., Chen, B., and Yao, S. Application of ultrasonic technique for extracting chlorogenic acid from *Eucommia ulmodies Oliv*. *Ultrasonics Sonochemistry*, 12, 295-300, 2005.
117. Liu, Q., Cai, W., and Shao, X. Determination of seven polyphenols in water by high performance liquid chromatography combined with preconcentration. *Talanta*, 77(2), 679-683, 2008.
118. Liu, X., Hu, Y., and Wei, D. Optimization of enzyme-based ultrasonic/microwave-assisted extraction and evaluation of antioxidant activity of orcinol glucoside from the rhizomes of *Curculigo orchioides Gaertn*. *Medicinal Chemistry Research*, 23(5), 2360-2367, 2014.
119. López-Ortiz, A., Méndez-Lagunas, L. L., Delesma, C., Longoria, A., Escobar, J., and Muñiz, J. Understanding the drying kinetics of phenolic compounds in strawberries: An experimental and density functional theory study. *Innovative Food Science & Emerging Technologies*, 60, 102283, 2020.
120. Luthria, D. L., and Pastor-Corrales, M. A. Phenolic acids content of fifteen dry edible bean (*Phaseolus vulgaris* L.) varieties. *Journal of Food Composition and Analysis*, 19(2-3), 205-211, 2006.
121. Ma, H., Diao, Y., Zhao, D., Li, K., and Kang, T. A new alternative to treat swine influenza a virus infection: extracts from *Terminalia chebula Retz*. *African Journal of Microbiology Research*, 4(6), 497-499, 2010.
122. Mahesh, R., Bhuvana, S., and Hazeena Begum, V. M. Effect of *Terminalia chebula* aqueous extract on oxidative stress and antioxidant status in the liver and kidney of young and aged rats. *Cell Biochemistry and Function: Cellular Biochemistry and its Modulation by Active Agents or Disease*, 27(6), 358-363, 2009.
123. Mahesh, R., Ramesh, T., Nagulendran, K. R., Velavan, S., and Begum, V. H. Effect of *Terminalia chebula* on monoamine oxidase and antioxidant enzyme activities in aged rat brain. *Pharmacognosy Magazine*, 3(12), 240, 2007.
124. Malekzadeh, F., Ehsanifar, H., Shahamat, M., Levin, M., and Colwell, R. R. Antibacterial activity of black myrobalan (*Terminalia chebula Retz*) against Helicobacter pylori. *International Journal of Antimicrobial Agents*, 18(1), 85-88, 2001.

125. Mansouri, A., Mirzabe, A. H., and Raufi, A. Physical properties and mathematical modeling of melon (*Cucumis melo* L.) seeds and kernels. *Journal of the Saudi Society of Agricultural Sciences*, 16(3), 218-226, 2017.

126. Manuwa, S. I., and Muhammad, H. A. Effects of moisture content and compression axis on mechanical properties of Shea kernel. *Journal of Food Engineering*, 105(1), 144-148, 2011.

127. Marathe, S. J., Jadhav, S. B., Bankar, S. B., Dubey, K. K., and Singhal, R. S. Improvements in the extraction of bioactive compounds by enzymes. *Current Opinion in Food Science*, 2019.

128. Mard, S. A., Veisi, A., Naseri, M. K. G., and Mikaili, P. Spasmogenic activity of the seed of *Terminalia chebula Retz* in rat small intestine: in vivo and in vitro studies. *The Malaysian Journal of Medical Sciences: MJMS*, 18(3), 18-26, 2011.

129. Maroulis, Z. B., Krokida, M. K., and Rahman, M. S. (2002). A structural generic model to predict the effective thermal conductivity of fruits and vegetables during drying. *Journal of Food Engineering*, 52(1), 47-52, 2002.

130. Maruthappan, V., and Shree, K. S. Hypolipidemic activity of Haritaki (*Terminalia chebula*) in atherogenic diet induced hyperlipidemic rats. *Journal of Advanced Pharmaceutical Technology & Research*, 1(2), 229-235, 2010.

131. Meng, J. C., Zhu, Q. X., and Tan, R. X. New antimicrobial mono-and sesquiterpenes from Soroseris hookeriana subsp. erysimoides. *Planta Medica*, 66(06), 541-544, 2000.

132. Merken, H. M., and Beecher, G. R. Measurement of food flavonoids by high-performance liquid chromatography: a review. *Journal of Agricultural and Food Chemistry*, 48(3), 577-599, 2000.

133. Micard, V., C. M. G., C. Renard., and J. F. Thibault. Studies on the enzymic release of ferulic acid from the sugar-beet pulp. *LWT-Food Science and Technology*, 27(1), 59-66, 1994.

134. Milojevic, S., Newton, J. M., Cummings, J. H., Gibson, G. R., Botham, R. L., Ring, S. G., and Allwood, M. C. Amylose as a coating for drug delivery to the colon: Preparation and in vitro evaluation using 5-aminosalicylic acid pellets. *Journal of controlled release*, 38(1), 75-84, 1996.

135. Mimica-Dukić, N., Božin, B., Soković, M., Mihajlović, B., and Matavulj, M. Antimicrobial and antioxidant activities of three Mentha species essential oils. *Planta Medica*, 69(05), 413-419, 2003.

136. Moeslinger, T., Friedl, R., Volf, I., Brunner, M., Koller, E., and Spieckermann, P. G. Inhibition of inducible nitric oxide synthesis by the herbal preparation Padma 28 in macrophage cell line. *Canadian Journal of Physiology and Pharmacology*, 78(11), 861-866, 2008.

137. Mustafa, A., and Turner, C. Pressurized liquid extraction as a green approach in food and herbal plants extraction: A review. *Analytica Chimica Acta*, 703(1), 8-18, 2011.

138. Muzaffar, K., and Kumar, P. Moisture sorption isotherms and storage study of spray dried tamarind pulp powder. *Powder Technology*, 291, 322-327, 2016.

139. Na, M., Bae, K., Sik Kang, S., Sun Min, B., Kuk Yoo, J., Kamiryo, Yu-ichiro Senoo., and Miwa, N. Cytoprotective effect on oxidative stress and inhibitory effect on cellular aging of *Terminalia chebula Retz.* fruit. *An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, 18(9), 737-741, 2004.

140. Naik, G. H., Priyadarsini, K. I., Naik, D. B., Gangabhagirathi, R., and Mohan, H. Studies on the aqueous extract of *Terminalia chebula* as a potent antioxidant and a probable radioprotector. *Phytomedicine,* 11(6), 530-538, 2004.

141. Naik, G. H., Priyadarsini, K. I., Satav, J. G., Banavalikar, M. M., Sohoni, D. P., Biyani, M. K., and Mohan, H. Comparative antioxidant activity of individual herbal components used in Ayurvedic medicine. *Phytochemistry*, 63(1), 97-104, 2003.

142. Nair, V., Singh, S., and Gupta, Y. K. Anti-arthritic and disease modifying activity of *Terminalia chebula Retz*. in experimental models. *Journal of Pharmacy and Pharmacology*, 62(12), 1801-1806, 2010.

143. Nakilcioglu-Taş, E., and Otleş, S. Degradation kinetics of bioactive compounds and antioxidant capacity of Brussels sprouts during microwave processing. *International journal of food properties*, 20, S2798-S2809, 2017.

144. Nedovic, V., Kalusevic, A., Manojlovic, V., Levic, S., and Bugarski, B. An overview of encapsulation technologies for food applications. *Procedia Food Science*, 1, 1806-1815, 2011.

145. Neirynck, N., Dewettinck, K., and Van der Meeren, P. Influence of pH and biopolymer ratio on sodium caseinate—guar gum interactions in aqueous solutions and in O/W emulsions. *Food Hydrocolloids,* 21(5-6), 862-869, 2007.

146. Nguyen, P. T., Kravchuk, O., Bhandari, B., and Prakash, S. Effect of different hydrocolloids on texture, rheology, tribology and sensory perception of texture and mouthfeel of low-fat pot-set yoghurt. *Food Hydrocolloids*, 72, 90-104, 2017.
147. Oancea, S., Daniela, G., and Otto, K. The effect of ultrasonic pretreatment and sample preparation on the extraction yield of antioxidant compounds and activity of black currant fruits. *Acta Chimica Slovenica*, 62(1), 242-248, 2014.
148. O'connell, J. E., and P. F. Fox. Proposed mechanism for the effect of polyphenols on the heat stability of milk. *International Dairy Journal*, 9(8), 523-536, 1999.
149. Olajide, J. O., and Igbeka, J. C. Some physical properties of groundnut kernels. *Journal of food engineering*, 58(2), 201-204, 2003.
150. Olaoye, J. O. Research Note (Postharvest Technology): Some Physical Properties of Castor Nut relevant to the Design of Processing Equipment. *Journal of agricultural Engineering research*, 77(1), 113-118, 2000.
151. O'riordan, K., Andrews, D., Buckle, K., and Conway, P. Evaluation of microencapsulation of a Bifidobacterium strain with starch as an approach to prolonging viability during storage. *Journal of applied microbiology*, 91(6), 1059-1066, 2001.
152. Parris, N., Cooke, P. H., and Hicks, K. B. Encapsulation of essential oils in zein nanospherical particles. *Journal of agricultural and food chemistry*, 53(12), 4788-4792, 2005.
153. Patel, M., Pradhan, R., and Naik, S. Physical properties of fresh mahua. *International Agrophysics*, 25(3), 2011.
154. Pathak, S. S., Pradhan, R. C., and Mishra, S. Physical characterization and mass modeling of dried *Terminalia chebula* fruit. *Journal of Food Process Engineering*, 42(3), 2019.
155. Patras, A., Brunton, N. P., Da Pieve, S., and Butler, F. Impact of high pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purées. *Innovative Food Science & Emerging Technologies*, 10(3), 308-313, 2009.
156. Peker, H., and Arslan, S. Effects of addition of locust bean gum on sensory, chemical, and physical properties of low-fat yoghurt. *Journal of Food, Agriculture & Environment*, 11(2), 274-277, 2013.

157. Perdomo, J., Cova, A., Sandoval, A. J., García, L., Laredo, E., and Müller, A. J. Glass transition temperatures and water sorption isotherms of cassava starch. *Carbohydrate polymers*, 76(2), 305-313, 2009.

158. Perina, N. P., Granato, D., Hirota, C., Cruz, A. G., Bogsan, C. S. B., and Oliveira, M. N. D. Effect of vegetal-oil emulsion and passion fruit peel-powder on sensory acceptance of functional yogurt. *Food Research International*, 70, 134-141, 2015.

159. Perrechil, F. A., Braga, A. L. M., and Cunha, R. L. Interactions between sodium caseinate and LBG in acidified systems: Rheology and phase behavior. *Food Hydrocolloids*, 23(8), 2085-2093, 2009.

160. Pietta, P. G. Flavonoids as antioxidants. *Journal of Natural Products,* 63(7), 1035-1042, 2000.

161. Pinelo, M., Rubilar, M., Jerez, M., Sineiro, J., and Núñez, M. J. Effect of solvent, temperature, and solvent-to-solid ratio on the total phenolic content and antiradical activity of extracts from different components of grape pomace. *Journal of Agricultural and Food Chemistry*, 53(6), 2111-2117, 2005.

162. Pinheiro, J., Alegria, C., Abreu, M., Gonçalves, E. M., and Silva, C. L. Kinetics of changes in the physical quality parameters of fresh tomato fruits (*Solanum lycopersicum*, cv.'Zinac') during storage. *Journal of Food Engineering*, 114(3), 338-345, 2013.

163. Porter, L. J., and Hemingway, R. W. Significance of the condensed tannins. In *Natural Products of Woody Plants* (pp. 988-1027). Springer, Berlin, Heidelberg, 1989.

164. Pradhan, R. C., Naik, S. N., Bhatnagar, N., and Vijay, V. K. Moisture-dependent physical properties of jatropha fruit. *Industrial crops and products*, 29(2-3), 341-347, 2009.

165. Pradhan, R. C., Said, P. P., and Singh, S. Physical properties of bottle gourd seeds. *Agricultural Engineering International: CIGR Journal*, 15(1), 106-113, 2013.

166. Prasad, L., Khan, T. H., Jahangir, T., and Sultana, S. Chemomodulatory effects of *Terminalia chebula* against nickel chloride induced oxidative stress and tumor promotion response in male Wistar rats. *Journal of Trace Elements in Medicine and Biology*, 20(4), 233-239, 2006.

167. Pratibha, N., Saxena, V. S., Amit, A., D'souza, P., Bagchi, M., and Bagchi, D. Anti-inflammatory activities of Aller-7, a novel polyherbal formulation for allergic rhinitis. *International Journal of Tissue Reactions*, 26(1-2), 43-51, 2004.

168. Quispe-Condori, S., Saldaña, M. D., and Temelli, F. Microencapsulation of flax oil with zein using spray and freeze drying. *LWT-Food Science and Technology,* 44(9), 1880-1887, 2011.

169. Rafiee, S., Jahromi, M. K., Jafari, A., Sharifi, M., Mirasheh, R., and Mobli, H. Determining some physical properties of bergamot (*Citrus medica*). *International Agrophysics*, 21(3), 293-297, 2007.

170. Rai, A. K., and Joshi, R. Evaluation of antimicrobial properties of fruit extracts of *Terminalia chebula* against dental caries pathogens. *Jundishapur Journal Microbiology*, 2(3): 105-111, 2009.

171. Rathinamoorthy, R., and G. Thilagavathi. Optimization of process conditions of cotton fabric treatment with *Terminalia chebula* extracts for antibacterial application. *Indian Journal of Fibre and Textile Research*, 38(3), 2013.

172. Reddy, D. B., Reddy, T. C. M., Jyotsna, G., Sharan, S., Priya, N., Lakshmipathi, V., and Reddanna, P. Chebulagic acid, a COX–LOX dual inhibitor isolated from the fruits of *Terminalia chebula Retz*., induces apoptosis in COLO-205 cell line. *Journal of Ethnopharmacology*, 124(3), 506-512, 2009.

173. Robbins, R. J. Phenolic acids in foods: an overview of analytical methodology. *Journal of Agricultural and Food Chemistry*, 51(10), 2866-2887, 2003.

174. Rocha, G. A., Fávaro-Trindade, C. S., and Grosso, C. R. F. Microencapsulation of lycopene by spray drying: characterization, stability and application of microcapsules. *Food and bioproducts processing*, 90(1), 37-42, 2012.

175. Ross, K. A., Beta, T., and Arntfield, S. D. A comparative study on the phenolic acids identified and quantified in dry beans using HPLC as affected by different extraction and hydrolysis methods. *Food Chemistry*, 113(1), 336-344, 2009.

176. Rudy, S., Dziki, D., Krzykowski, A., Gawlik-Dziki, U., Polak, R., Różyło, R., and Kulig, R. Influence of pre-treatments and freeze-drying temperature on the process kinetics and selected physico-chemical properties of cranberries (*Vaccinium macrocarpon Ait*.). *LWT-Food Science and Technology*, 63(1), 497-503, 2015.

177. Rurush, E., Alvarado, M., Palacios, P., Flores, Y., Rojas, M. L., and Miano, A. C. Drying kinetics of blueberry pulp and mass transfer parameters: Effect of hot air

and refractance window drying at different temperatures. *Journal of Food Engineering*, 320, 110929, 2022.

178. Sahay, K. M., and Singh, K. K. *Unit Operations of Agricultural Processing*. Vikas Publishing House Pvt. Ltd, 2001.
179. Saleem, A., Husheem, M., Härkönen, P., and Pihlaja, K. Inhibition of cancer cell growth by crude extract and the phenolics of *Terminalia chebula* Retz. fruit. *Journal of Ethnopharmacology*, 81(3), 327-336, 2002.
180. Sato, Y., Oketani, H., Singyouchi, K., Ohtsub, T., Kihara, M., Shibata, H., and Higuti, T. Extraction and purification of effective antimicrobial constituents of *Terminalia chebula* Retz. against methicillin-resistant *Staphylococcus aureus*. *Biological and Pharmaceutical Bulletin*, 20(4), 401-404, 1997.
181. Senthilkumar, G. P., and Subramanian, S. P. Biochemical studies on the effect of *Terminalia chebula* on the levels of glycoproteins in streptozotocin-induced experimental diabetes in rats. *Journal of Applied Biomedicine*, 6(2), 105-115, 2008.
182. Šeregelj, V., Pezo, L., Šovljanski, O., Lević, S., Nedović, V., Markov, S., and Ćetković, G. New concept of fortified yogurt formulation with encapsulated carrot waste extract. *LWT*, 138, 110732, 2021.
183. Sharma, P., Prakash, T., Kotresha, D., Ansari, M. A., Sahrm, U. R., Kumar, B., and Goli, D. Antiulcerogenic activity of *Terminalia chebula* fruit in experimentally induced ulcer in rats. *Pharmaceutical Biology*, 49(3), 262-268, 2011.
184. Sheng, Z., Zhao, J., Muhammad, I., and Zhang, Y. Optimization of total phenolic content from *Terminalia chebula* Retz. fruits using response surface methodology and evaluation of their antioxidant activities. *PloS one*, 13(8), 2018.
185. Shin, T. Y., Jeong, H. J., Kim, D. K., Kim, S. H., Lee, J. K., Chae, B. S., and Lee, Y. M. Inhibitory action of water soluble fraction of *Terminalia chebula* on systemic and local anaphylaxis. *Journal of Ethnopharmacology*, 74(2), 133-140, 2001.
186. Shukla, R., and Cheryan, M. Zein: the industrial protein from corn. *Industrial crops and products*, 13(3), 171-192, 2001.
187. Silva, M. P., Mesquita, M. D. S., Rubio, F. T., Thomazini, M., and Favaro-Trindade, C. S. Fortification of yoghurt drink with microcapsules loaded with *Lacticaseibacillus paracasei* BGP-1 and guarana seed extract. *International Dairy Journal*, 125, 105230, 2022.

188. Ślusarczyk, S., Hajnos, M., Skalicka-Woźniak, K., and Matkowski, A. Antioxidant activity of polyphenols from Lycopus lucidus Turcz. *Food Chemistry*, 113(1), 134-138, 2009.

189. Sohni, Y. R., Kaimal, P., and Bhatt, R. M. The antiamoebic effect of a crude drug formulation of herbal extracts against Entamoeba histolytica in vitro and in vivo. *Journal of Ethnopharmacology*, 45(1), 43-52, 1995.

190. Sormoli, M. E., and Langrish, T. A. Moisture sorption isotherms and net isosteric heat of sorption for spray-dried pure orange juice powder. *LWT-Food Science and Technology*, 62(1), 875-882, 2015.

191. Stapleton, S. L., Thompson, P. A., Ou, C. N., Berg, S. L., McGuffey, L., Gibson, B., and Blaney, S. M. Plasma and cerebrospinal fluid pharmacokinetics of valproic acid after oral administration in non-human primates. *Cancer Chemotherapy and Pharmacology*, 61(4), 647-652, 2008.

192. Stępień, A., Witczak, M., and Witczak, T. Moisture sorption characteristics of food powders containing freeze dried avocado, maltodextrin and inulin. *International journal of biological macromolecules*, 149, 256-261, 2020.

193. Suchalatha, S., and Devi, C. S. Protective effect of *Terminalia chebula* against experimental myocardial injury induced by isoproterenol. *Indian Journal Experimental Biology* 42(2): 174-178, 2004.

194. Suchalatha, S., and Devi, C. S. S. Protective effect of *Terminalia chebula* against lysosomal enzyme alterations in isoproterenol-induced cardiac damage in rats. *Experimental & Clinical Cardiology*, 10(2), 91, 2005.

195. Summen, M. A., and Erge, H. S. Thermal degradation kinetics of bioactive compounds and visual color in raspberry pulp. *Journal of Food Processing and Preservation*, 38(1), 551-557, 2014.

196. Suslick, K. S., Doktycz, S. J., and Flint, E. B. On the origin of sonoluminescence and sonochemistry. *Ultrasonics*, 28(5), 280-290, 1990.

197. Tamhane, M. D., Thorat, S. P., Rege, N. N., and Dahanukar, S. A. Effect of oral administration of *Terminalia chebula* on gastric emptying: an experimental study. *Journal of Postgraduate Medicine*, 43(1), 12-13, 1997.

198. Tasaduq, S. A., Singh, K., Sethi, S., Sharma, S. C., Bedi, K. L., Singh, J., and Johri, R. K. Hepatocurative and antioxidant profile of HP-1, a polyherbal phytomedicine. *Human & Experimental Toxicology*, 22(12), 639-645, 2003.

199. Tiwari, B. K. Ultrasound: A clean, green extraction technology. *Trends in Analytical Chemistry*, 71, 100-109, 2015.
200. Toledo, Á., and Burlingame, B. Biodiversity and nutrition: A common path toward global food security and sustainable development. *Journal of Food Composition and Analysis*, 19(6-7), 477-483, 2006.
201. Tsao, R., and Yang, R. Optimization of a new mobile phase to know the complex and real polyphenolic composition: towards a total phenolic index using high-performance liquid chromatography. *Journal of Chromatography A*, 1018(1), 29-40, 2003.
202. Tubtimdee, C., and Shotipruk, A. Extraction of phenolics from *Terminalia chebula Retz* with water–ethanol and water–propylene glycol and sugaring-out concentration of extracts. *Separation and Purification Technology*, 77(3), 339-346, 2011.
203. Valenzuela, A., Nieto, S., Cassels, B. K., and Speisky, H. Inhibitory effect of boldine on fish oil oxidation. *Journal of the American Oil Chemists' Society*, 68(12), 935-937, 1991.
204. Vani, T., Rajani, M., Sarkar, S., and Shishoo, C. J. Antioxidant properties of the ayurvedic formulation triphala and its constituents. *International Journal of Pharmacognosy*, 35(5), 313-317, 1997.
205. Varier, A. Dictionary of Indian raw materials & Industrial products. *Publication and Information Directorate Council of Scientific & Industrial Research*, 387, 2002.
206. Viskelis, P., Rubinskienė, M., Jasutienė, I., Šarkinas, A., Daubaras, R., and Česonienė, L. Anthocyanins, antioxidative, and antimicrobial properties of American cranberry (*Vaccinium macrocarpon Ait*.) and their press cakes. *Journal of Food Science*, 74(2), C157-C161, 2009.
207. Vital, A. C. P., Goto, P. A., Hanai, L. N., Gomes-da-Costa, S. M., de Abreu Filho, B. A., Nakamura, C. V., and Matumoto-Pintro, P. T. Microbiological, functional and rheological properties of low-fat yoghurt supplemented with *Pleurotus ostreatus* aqueous extract. *LWT-Food Science and Technology*, 64(2), 1028-1035, 2015.
208. Vivek, K., Mishra, S., and Pradhan, R. C. Physicochemical characterization and mass modelling of Sohiong (*Prunus nepalensis* L.) fruit. *Journal of Food Measurement and Characterization*, 12(2), 923-936, 2018.

209. Vonshak, A., Barazani, O., Sathiyamoorthy, P., Shalev, R., Vardy, D., and Golan-Goldhirsh, A. Screening South Indian medicinal plants for antifungal activity against cutaneous pathogens. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, 17(9), 1123-1125, 2003.

210. Wandkar, S. V., Ukey, P. D., and Pawar, D. A. Determination of physical properties of soybean at different moisture levels. *Agricultural Engineering International: CIGR Journal*, 14(2), 138-142, 2012.

211. Wang, P., Ma, C., Chen, S., Zhu, S., Lou, Z., and Wang, H. Ionic liquid-based ultrasonic/microwave-assisted extraction of steroidal saponins from *Dioscorea zingiberensis* CH Wright. *Tropical Journal of Pharmaceutical Research*, 13(8), 1339-1345, 2014.

212. Wing, R. E., Maiti, S., and Doane, W. M. Amylose content of starch controls the release of encapsulated bioactive agents. *Journal of controlled release*, 7(1), 33-37, 1998.

213. Xiao, Z., Lester, G. E., Luo, Y., and Wang, Q. Assessment of vitamin and carotenoid concentrations of emerging food products: edible microgreens. *Journal of Agricultural and Food Chemistry*, 60(31), 7644-7651, 2012.

214. Xie, Y. L., Zhou, H. M., Liang, X. H., He, B. S., and Han, X. X. Study on the morphology, particle size and thermal properties of vitamin A microencapsulated by starch octenylsucciniate. *Agricultural Sciences in China*, 9(7), 1058-1064, 2010.

215. Yadav, K., Bajaj, R. K., Mandal, S., Saha, P., and Mann, B. Evaluation of total phenol content and antioxidant properties of encapsulated grape seed extract in yoghurt. *International Journal of Dairy Technology*, 71(1), 96-104, 2018.

216. Yangilar, F., and Yildiz, P. O. Effects of using combined essential oils on quality parameters of bio-yogurt. *Journal of Food Processing and Preservation*, 42(1), 2018.

217. Yao, Y. M., Bahrami, S., Leichtfried, G., Redl, H., and Schlag, G. Pathogenesis of hemorrhage-induced bacteria/endotoxin translocation in rats. Effects of recombinant bactericidal/permeability-increasing protein. *Annals of Surgery*, 221(4), 398, 1995.

218. Yin, J., Seong. L. H., and Myeong. H. W. Antioxidant and antidiabetic activities of extracts from *Cirsium japonicum* roots. *Nutrition Research and Practice*, 2(4), 247-251, 2008.

219. Yoshimura, M., Watanabe, Y., Kasai, K., Yamakoshi, J., and Koga, T. Inhibitory effect of an ellagic acid-rich pomegranate extract on tyrosinase activity and ultraviolet-induced pigmentation. *Bioscience, Biotechnology, and Biochemistry*, 69(12), 2368-2373, 2005.

220. Zadernowski, R., Czaplicki, S., and Naczk, M. Phenolic acid profiles of mangosteen fruits (*Garcinia mangostana*). *Food Chemistry*, 112(3), 685-689, 2009.

221. Zeng, H., Zhang, Y., Lin, S., Jian, Y., Miao, S., and Zheng, B. Ultrasonic–microwave synergistic extraction (UMSE) and molecular weight distribution of polysaccharides from *Fortunella margarita* (Lour.) Swingle. *Separation and Purification Technology*, 144, 97-106, 2015.

222. Zhang, L. Comparison of extraction effect of active ingredients in traditional Chinese medicine compound preparation with two different method. *Heilongjiang Xumu Shouyi*, 9, 132-133, 2013.

223. Zhao, J., and Whistler, R. L. Spherical aggregates of starch granules as flavor carriers. *Food technology (Chicago)*, 48(7), 104-105, 1994.

224. Zhong, Q., and Jin, M. Zein nanoparticles produced by liquid–liquid dispersion. *Food Hydrocolloids*, 23(8), 2380-2387, 2009.

225. Zhong, Q., Jin, M., Xiao, D., Tian, H., and Zhang, W. Application of supercritical anti-solvent technologies for the synthesis of delivery systems of bioactive food components. *Food Biophysics*, 3(2), 186-190, 2008.

226. Zosel, A. Der Schubmodul von Hochpolymeren als Funktion von Druck und Temperatur. *Kolloid-Zeitschrift und Zeitschrift für Polymere*, 199(2), 113-125, 1964.

227. Zou, T., Li, Z., Percival, S. S., Bonard, S., and Gu, L. Fabrication, characterization, and cytotoxicity evaluation of cranberry procyanidins-zein nanoparticles. *Food hydrocolloids*, 27(2), 293-300, 2012.

228. Zougagh, M., Valcárcel, M., and Rıos, A. (2004). Supercritical fluid extraction: a critical review of its analytical usefulness. *Trends in Analytical Chemistry*, 23(5), 399-405, 2004.