Chapter 1

Introduction

1.1 Genus of banana

Bananas are one of the most popular fruits that originated from the largest flowering herbaceous plant a family of *Musaceae* [35]. The genus of banana varies with different groups as diploid, triploid, and tetraploid. Genome groups of the banana are AA, BB or AB, AAA, AAB, ABB, AAAA, AAAB, AABB, and ABBB. These hybrid genomes of bananas originated from *Musa acuminate* (genome A) and *Musa balbisiana* (genome B) [11]. Hybrid bananas are originated by the sharing of chromosomes within varieties. Bananas with genome AA and AAA are the sweet desert-type varieties inherited from *Musa acuminate*. The most commonly available varieties of bananas are AAB and ABB where AAB originated by sharing two chromosomes of *Musa acuminate* and one chromosome of *Musa balbisiana*. Similarly, ABB originated by sharing one chromosome of *Musa acuminate* and two chromosomes of *Musa balbisiana*. According to the FAO [23], there are more than 1000 varieties of banana, where, the Cavendish variety is contributing 47% of the whole global banana production. Bananas are grown for many purposes. Desert-sweet types of bananas generally can be eaten raw which is soft and easily digestible when ripe. Plantains are the type of banana that is normally cooked before consumption, which is mostly starchy even after ripe. A banana variety, *Musa balbisiana* (ABB) known as bhimkol or athiya kol is a highly demanded variety of bananas in Assam, India, due to its medicinal beliefs. Mostly *Musa balbisiana* is considered to be inedible because of its seed content, hence moreover pondered as an underutilized variety in most of the regions in several countries [69].

1.2 Global scenario of banana

Around 5.6 million hectares of land are stated for the cultivation of bananas globally according to the FAOSTAT report of 2017 [23]. Asia leads the largest production of bananas worldwide (Fig. 1.1), where India produces the highest at 29 million tonnes, then China at 11 million tonnes, and thirdly, the Philippines, Ecuador, and Brazil. In Brazil, over 480,000 hectares of bananas are planted per year [61], producing about 105 million tons of waste. From the environmental point of view, it is essential to reuse this waste because it is being improperly discarded in landfills, contributing to the generation of environmental problems, or it is left in the plantations, where it is used as a soil cover [44].

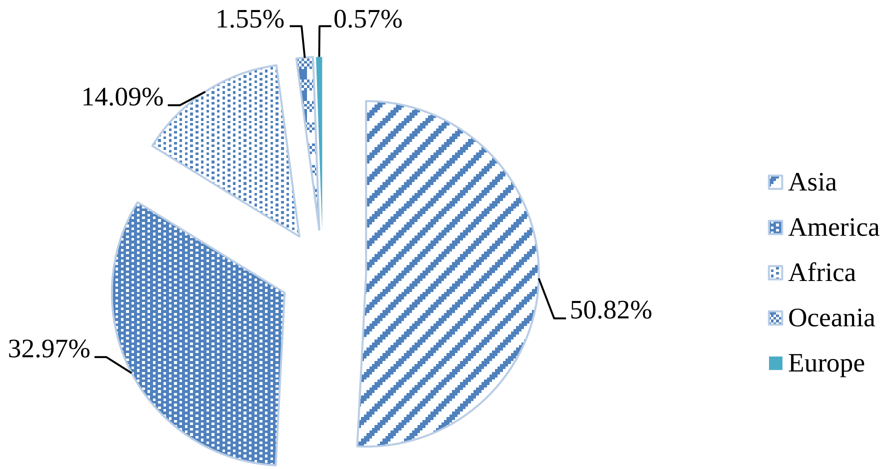

Fig. 1.1 Global production of banana

1.3 Banana blossom

The banana inflorescence is an elongated, oval-shaped, dark purple bud as shown in Fig. 1.2. White flowers are clustered in whorled double rows along the floral stack [67]. Each stem of the banana plant normally produces a single, sterile, male banana flower, also known as the banana heart or blossom. The female flowers appear further up the stem and produce the actual fruit without fertilization. Firstly its appearance is bulky, long-oval, narrowing, and purple-colored bud. Later on the slender, nectar-rich, tube-like, toothed, white flower slowly opens up as described by [22], falling with bract, compound tepal cream with yellow lobes, translucent white free tepal, oval, triangular apex; five stamens, yellowish, exerted, white filament; straight style, same level exertion style, cream stigma, arched ovary, cream [69]. Bhimkol blossom is cooked to serve in preparing different types of cuisines like raw salad, fried snacks, soup, etc. [7]. The genus is native throughout the Indo-Malaysian region, in tropical and subtropical areas from Sri Lanka and eastern India, across south China and Southeast Asia to the southwest Pacific and northern Australia, but it is widely grown in all tropical regions of the world [35].

Fig. 1.2 Bhimkol (*Musa balbisianana*) banana blossom

1.4 Biochemical and phytochemicals

1.4.1 Nutrition and biochemical

Quantities of nutrient requirements are mobility of nutrients contained in the soil, mobility of nutrients within plants, and functions in plants. Classification based on the quantity of nutrients required: basic, macro, and micro nutrients. Basic nutrients constitute 96% of the total dry matter of plants [50]. They are carbon, hydrogen, and oxygen, among these, carbon and oxygen constitute 45% each and hydrogen is 6%. Macronutrients are the nutrients that are required by plants in large quantities, hence they are called macro or major nutrients. There are nine macronutrients present are nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, carbon, hydrogen, and oxygen. Macronutrients have again two categories, primary nutrients; those are among macronutrients, nitrogen, phosphorus, and potassium are known as primary nutrients which are required in a proper ratio for successful crop development and next to primary nutrients, calcium, magnesium, and sulphur are also known as secondary nutrients. Micronutrients are the nutrients required by plants in small quantities and are also known as minor or trace elements. There are eight numbers of micronutrients, such as manganese, iron, zinc, copper, boron, molybdenum, chlorine, and cobalt [50]. Banana blossoms are reported to be rich in nutrients (Table 1.1) with abundant fibers [11].

Table 1.1 Nutritional compositions of banana blossom

Constituents		Compositions	References
Proximate compositions (%)	Moisture content	9.53	Adeolu and Enesi [2]
	Crude fat	1.83	Adeolu and Enesi [2]
	Crude fiber	8.47	Adeolu and Enesi [2]
	Crude protein	11.47	Adeolu and Enesi [2]
	Carbohydrate	60.87	Adeolu and Enesi [2]
	Ash	7.85	Adeolu and Enesi [2]
	TDF	42.12	Deka and Talukdar [17]
	IDF	29.21	Deka and Talukdar [17]
	SDF	12.91	Deka and Talukdar [17]
Minerals (ppm)	Al	0.65	Deka and Talukdar [17]
	V	0.41	Deka and Talukdar [17]
	Mn	0.05	Deka and Talukdar [17]
	Fe	0.67	Deka and Talukdar [17]
	Co	0.07	Deka and Talukdar [17]
	Ni	0.13	Deka and Talukdar [17]
	Cu	0.54	Deka and Talukdar [17]
	Zn	0.12	Deka and Talukdar [17]
	Cd	0.03	Deka and Talukdar [17]
	Pb	0.66	Deka and Talukdar [17]
	Na	7000	Deka and Talukdar [17]
	K	43000	Deka and Talukdar [17]

The guidance of mineral nutritional intake for 4-6 years old children (China Nutrition Institute, 2001) indicated that banana blossom is a good mineral source of magnesium, iron, copper, and potassium. Apart from nutritional values, fatty acids and sterols are also the major families of lipophilic components in the floral stalk [64].

Phytochemicals are classified mostly into major classes; terpenoids, phenolic metabolites, and alkaloids and other nitrogen-containing plant components as reported by Younas et al. [80]. Banana blossoms; *Musa paradisiaca*, *Musa acuminate* [68], *Musa* sp. var. Nanjangud rasa bale [56], *Musa sapientum* [37] are reported to contain a significant amount of phytochemicals such as Terpenoids (Saponin), alkaloids, phenolic compounds (flavonoids, tannins, phenolic acids, etc.) [2, 41] and steroids [41] (Table 1.2). Their concentrations vary with the variety of banana cultivars. Banana blossoms of different cultivars might possess different levels of phenolic compounds due to many reasons [42]. According to Mathur et al. [43], the presence of tannin, glycosides of delphinidin, and cyanidin give the dark red-brown color of the bract. According to the Saikia and Mahanta [59] study, all the banana blossom showed a good amount of phytochemical content and antioxidant activity.

Table 1.2 Phytochemical compositions of *Musa paradisiaca* bract

Phytochemicals	Contents (mg/100g)	References
Flavonoids	145	Adeolu and Enesi [2]
Tannins	115	Adeolu and Enesi [2]
Total phenolic content	1020	Sheng et al. [65]
Saponins	563.33	Adeolu and Enesi [2]
Phytates	46.67	Adeolu and Enesi [2]
Oxalates	30	Adeolu and Enesi [2]
Vitamin E	8.7	Sheng et al. [65]
Alkaloids	24	Adeolu and Enesi [2]

1.4.2 Phenolic compounds

Phenolic compounds are the largest group of phytochemicals [18]. Phenolic compounds are the compounds where the hydroxyl group/s (OH) are present in a class of chemical compounds and the (OH) group is bonded directly with an aromatic hydrocarbon group. Phenol (C_6H_5OH) is considered the simplest class of natural compounds as reported by Koche et al. [38]. Plant polyphenols are secondary metabolites that are widely distributed in plants. They can be distinguished by their water solubility, molecular weights, 12±16 phenolic groups, and 5±7 aromatics rings per 1000 relative molecular mass, their intermolecular complex formation, and their classification as condensed pro-anthocyanidins, galloyl, and hexa-hydroxydiphenoyl esters and derivatives as reported by Dillard & German (2000). Flavonoids are one of the major polyphenols and are largely distributed in flowers as reported by Tabasum et al. [70]. In banana blossom, phenolic compounds are the major phytochemicals present in the form of flavonoids, tannin, caffeic acids, etc. [2]. Anthocyanins, a subclass of flavonoids are important flower and fruit pigments [21]. According to Marikkar et al. [42], *Musa balbisiana* cv P. Abu (Abu) and *Musa balbisiana* cv P. Nipah (Nipah) contributes total phenolic content (TPC) 60.17 ± 0.50, 45.06 ± 2.40 mg of GAE/g and total flavonoid content (TFC) 29.33 ± 0.26 mg of QE/g (Table 1.2). According to Begum and Deka [11], the concentration of phytochemicals may decrease from the outer to the inner bract. That explains why, it is possible for instance that the sample taken from the outer skin layers compared to the inner tissues might contain higher phenolic content. The bract part of *Musa paradisiaca* was reported to contain anthocyanins such as delphinidin, pelargonidin, peonidin, and malvidin [41]. As the research outcome of Sasipriya et al. [60], the tannin content in banana blossom (*Musa paradisiaca* var. Monthan) is 15.05-298.79 mg TAE/g.

1.4.3 Terpenoids

Terpenoids contain natural components which are the byproducts of five carbon isoprene units. Most terpenoids have multiple cyclic structures that are not the same in their functional groups and basic carbon arrangement. It can be found in every class of living things and is considered as the largest group of naturally occurring secondary metabolites as reported by Koche et al. [38]. Saponin a phytochemical in the class of terpenoids is made of a steroid (or triterpene) group which is attached to a sugar moiety as reported by Shahidi [63] and it is found in very high concentration, 563.33 mg/100g in the bract and 1430 mg/100g in the whole part of banana flower as Adeolu and Enesi [2] study.

1.4.4 Alkaloids

Alkaloids are natural plant compounds containing heterocyclic nitrogen atoms and are always basic as mentioned by Koche et al. [38]. Alkaloids consist of amaryllidaceae, betalain, diterpenoid, indole, isoquinoline, lycopodium, monoterpene, sesquiterpene, peptide, pyrrolidine and piperidine, pyrrolizidine, quinoline, quinolizidine, steroidal, and tropane compounds. Other nitrogen-containing compounds consist of non-protein amino acids, amines, cyanogenic glycosides, glucosinolates, and purines and pyrimidines as reported by Dillard and German [18]. According to Adeolu and Enesi [2], alkaloid is present in banana blossom as a secondary metabolite in the amount of 1560 mg/100g.

1.4.5 Volatile compounds

Plants, as non-moving living organisms have to adjust to the surrounding environment in their life cycle. Being immobility nature, they have evolved various natural mechanisms for their interactions with the environment by producing arrays of natural volatile compounds from their plant parts like leaves, blossoms, and fruits into the atmosphere and from roots into the growing medium as described by Dudareva et al. [20]. In banana blossoms, Wang et al. [75] identified 31 compounds comprise 97.78% of the total volatile compounds and also identified 16 compounds in banana bracts comprise 93.54% of the total volatile compounds. The highest concentrated volatile components reported are aldehydes (88.50%), ketones (0.63%), alcohols (1.64%), esters (1.37%), and hydrocarbons (4.37%). The main aldehydes were nonanal (72.67%), heptanal (7.27%), hexanal (4.80%), and octanal (1.99%).

1.4.6 Antioxidants

Antioxidants are an essential component that plays an important role in maintaining good health. There is a growth in research interest amongst scientific researchers in further investigating and isolating the secondary metabolites compounds from various types of plant sources with biological activities as reported by Amri and Hossain [5]. Antioxidants are mostly obtained from eatables and medicinal plants, such as fruits, vegetables, cereals, mushrooms, beverages, flowers, spices, and ancient medicinal herbs as described by Zhang et al. [82]. On the other side, most agricultural by-products are a good source of natural antioxidants. Mainly polyphenols (phenolic acids, flavonoids, anthocyanins, lignans, and stilbenes), carotenoids (xanthophylls and carotenes), and vitamins (vitamin E and C) are the natural antioxidants from plant materials as reported by Baiano and Del Nobile [9]. As per study reports of Peng et al. [52] and Amri and Hossain [5], natural antioxidants, mainly polyphenols, and carotenoids contribute a wide range of biological health effects, such as anti-inflammatory, antibacterial, antiviral, anti-aging, anticancer, etc.

According to Dahham et al. [15], banana fruits contribute physiological defense against oxidative and free radical reactions in the biological systems, as they contain a very good amount of antioxidant potential. As banana fruit, banana blossoms are also rich in antioxidant property that, contributes to physiological defense against oxidative and free-radical-mediated reactions in the biological systems. According to Marikkar et al. [42], *Musa balbisiana* cv P. Abu (Abu) and *Musa balbisiana* cv P. Nipah contributes ABTS (2,2'-azino-bis 3-ethylbenzothiazoline-6-sulphonic acid) radicals scavenging activity 9.18±0.13, 9.68±0.02 μmol of Trolox/g, DPPH (2,2-diphenyl-1-picrylhydrazyl) radicals scavenging activity 2.62±0.20, 16.80±2.82 μmol of Trolox/g and Ferric reducing antioxidant activity (Ferric reducing ability of plasma- FRAP) 70.70±3.27, 159.71±5.44 μmol of $FeSO_4$/g, respectively. Biochemical and phytochemicals present in blossoms are mainly responsible to possess antioxidant activities, functional activities, and health beneficial properties [11]

1.5 Medicinal properties of bhimkol blossom

Various parts of the banana plant such as the leaves, roots, and flowers have been used for medicinal purposes [49]. Apart from food uses of blossoms, they are also believed to possess many medicinal properties [42] as enlisted in Table 1.3. Banana blossoms are reported to treat some disorders such as diabetes, cancer [57], bronchitis, constipation, ulcers, lactating disorder [39], dysentery, menorrhagia [19], constipation, ulcer, diuretic problem, and wound healing problem [54]. It eases menstrual cramps, and cooked banana blossom increases the level of progesterone in the body and thereby reduce bleeding associated with menorrhagia [19]. The chloroform, water, and ethanol extract of

Musa sapientum blossoms were found to exhibit hypoglycaemic activity in alloxan diabetic rats [49]. Studies on the contents of vitamin C, tannin, myoinositol phosphates, and alpha-tocopherol in *Musa sapientium* blossom were reported [68]. The sap is also used to treat allergic reactions caused by bites and stings by insects [39]. Only a few studies were carried out on their nutritional value and dietary fiber content. There is little mention of their use in literature [25].

Table 1.3 Health beneficial properties of banana blossom

Health beneficial properties	References
Antidiabatic effect	Bhaskar et al. [13]
Anticarcinogenic effect	Revadigar et al. [57]
Antidiarrheal activity	Sumathy et al. [68]
Anti-inflammation	Sumathy et al. [68]
Hypoglycemic activity	Pari and Umamaheswari [51]
Hypocholesterolaemic activity	Wickramarachchi and Ranamukhaarachchi [76]
Antimicrobial activity	Sumathy et al. [68]
Antioxidant activity	Marikkar et al. [42]
Lactating agent	Singh et al. [67]

In today's modernized world, livelihood is leading the population towards profound change in terms of good diet habits with the aspiration of more natural and healthy food products [29]. Research on bioactive compounds especially in phytochemicals of natural food products possessing high antioxidant activities and health-beneficial properties has increased at a great pace [78].

1.6 Antidiabetic activity

Diabetes mellitus (DM) is a chronic metabolic disorder caused by the dysfunction of insulin that causes hyperglycemia [46]. It caused long-term damage, dysfunction, and failure of various organs. The World Health estimates that in 2030 about 366 million people will suffer from DM [73]. α- Glucosidase enzymes in the intestinal lumen and the brush border membrane play main roles in carbohydrate digestion to degrade starch and oligosaccharides to monosaccharides before they can be absorbed [81]. It was proposed that suppression of the activity of such digestive enzymes would delay the degradation of starch and oligosaccharides, which would, in turn, cause a decrease in the absorption of glucose and consequently the reduction of postprandial blood glucose level elevation [55]. α -Glucosidase inhibitor retards the digestion of carbohydrates and slows down their absorption. DM is strongly associated with oxidative stress, which can be a consequence of increased free radical production, reduced antioxidant defenses, or both [40]. Oxidative stress induced by hyperglycemia possibly causes the dysfunction of pancreatic b-cells and various forms of tissue damage in patients with DM. Banana blossoms could possess the capability to prevent diseases associated with abnormal blood sugar and AGEs levels, such as diabetes [67].

1.7 Extraction of Phytochemicals

The extraction of bioactive compounds from banana waste is an alternative method to ensure the efficient, inexpensive, and environmentally friendly use of this waste. These bioactive components can be used in foods, cosmetics, and in the pharmaceutical industries [36]. Some phytochemicals are thermolabile and sensitive to light and they interact with polar and non-polar solvents by different mechanisms. These characteristics can change the extraction yield and the quality of the extract recovered. The separation or the isolation of the target compounds from their original matrix is the method used to obtain these antioxidant substances. Extraction for bioactive compounds increases as the solvent polarity increases. According to Vuong et al. [74], in the determination and extraction of plant bioactive compounds, extracted compounds determined are highly dependent on the extraction parameters, dependent and independent variables including the stage of inflorescence maturity, geographical origin [33], handling and preparation of plant parts [34], selection of solvents and extraction conditions [74].

1.7.1 Conventional extraction

Conventional extraction techniques (centrifugation, steam distillation, and Soxhlet extraction, for instance) possess some drawbacks due to the use of high temperatures and/or high amounts of organic solvents; another limitation is that the steam distillation process can be used only to obtain volatile oils (mostly terpenes). These conventional techniques are being substituted by novel techniques, such as supercritical fluid extraction (SCFE); pressurized liquid extraction (PLE); microwave-assisted extraction (MAE); and ultrasound-assisted extraction (UAE), water addition increases the medium relative polarity and facilitates the propagation of the ultrasonic waves [47, 57].

1.7.2 Ultrasound assisted extraction

Ultrasound is the sound waves above the hearing limit of human beings. The UAE is a technique of extraction of phytochemicals, where sonic waves are employed in a sample medium that penetrate through cell membranes causing bubbling and rupture of the cell wall. This leads to the release of phytochemical compounds in the medium [26]. A frequency above 20 KHz is used. Extraction temperature, amplitude, and time can be set based on the requirements with adjustable probes. Many research reported that UAE is an effective technique of extraction with minimal operating cost, medium maintenance, and simple technique. It enhances 20 to 30% extraction efficiency in the extraction of polyphenols, antioxidants, and other compounds [733].

1.7.3 Supercritical fluid extraction

Supercritical fluid extraction is a process of extraction that takes place with the help of a fluid in a supercritical state [79]. Different fluids have their specific condition of parameters to be in a supercritical state. Mostly, CO_2 is used for supercritical fluid extraction. A supercritical state for CO_2 needs a condition of parameters set at a pressure of 73.8 bar and 30.9^{o}C temperature [58]. A supercritical fluid helps in the extraction of phytochemicals along with a co-solvent (*Viz.*, ethanol, methanol, a mixture of solvents, etc.) at or above the critical point of supercritical fluid. It is a highly efficient and sophisticated technique to extract heat-sensitive phytochemicals. High extraction efficiency for bioactive compounds has been reported to obtain which gives 71 to 78% extraction efficiency [53].

1.8 Characterization and identification of compounds

1.8.1 Spectroscopy

Structural classification and identification of compounds are mostly performed by spectroscopy and chromatography techniques [71]. The spectroscopy of a compound is measured by passing electromagnetic radiation through a compound and radiation absorbed by that compound is noted. The measured radiation is produced in the form of a spectrum, which is distinct to the certain chemical bonds of every compound. Spectroscopy mostly uses ultraviolet-visible (UV-visible), infrared (IR), radio frequency, and electron beams [16]. In UV-visible spectroscopy mostly, phenolic compounds are detected in the range of 254 to 360 nm [4]. IR- spectroscopies like Fourier transform infrared spectroscopy (FTIR) are the rapid and non-destructive techniques of structural identifiers. They characterize the structure of a compound by the vibrational spectral output. Different bonds exhibit diverse vibrational frequencies, which makes them specific and easy to identify any compound or molecule by the intensity of absorption of vibration by the molecular structural bonds [48]. Nuclear magnetic resonance (NMR) spectroscopy is also a technique that usually functions by the magnetic properties of certain atoms and nuclei. It depicts the magnetic intensity of the nucleus of the hydrogen atoms, carbon atoms, protons, and carbon isotopes and then expresses the spectral output [32]. These techniques are highly efficient which also helps to identify unknown and new compounds present in the medium. Mass spectroscopy is also a technique where a compound is identified by its molecular mass. Compounds are bombarded with electrons or laser which converts them to charged ions. It plots the intensity of fragmented ions against the mass by the charge (m/z) ratio of the ions [31].

1.8.2 Chromatography

Chromatography is a technique for the identification and separation of compounds with the help of their retention time versus the intensity of absorbance unit carried by a mobile phase through the stationary phase. The mobile phase or carrier gas may be in gas or liquid form. The stationary phase is the solid part or microscopic liquid layered in a solid phase. Chromatography is mainly divided in two techniques; liquid chromatography (LC) and gas chromatography (GC) [14]. Some of the chromatography techniques are column chromatography (using macroporous resins) [8], thin layer chromatography

(TLC), paper chromatography, reversed phase-high performance liquid chromatography (RP-HPLC), etc. The LC is mainly for non-volatile and heat-sensitive compounds whereas GC is for gases, mixtures, and volatile compounds. When compounds are loaded in the chromatography system, they elute based on their affinities with the stationary phase, hence having a different retention time for each certain compound [14].

1.9 Encapsulation of phytochemicals

Encapsulation involves formulating an active ingredient with secondary materials and preparation of a capsule that isolates the bioactive compound from an undesirable environment until it is released upon exposure to the desired stimulus [10]. Bioactive compounds with various potential health benefits are included, too [3]. If the particle size ranged from 3 to 800 µm, these are called microspheres, and the technology involved is termed microencapsulation [28]. According to their morphology, microspheres can be classified as mononuclear, polynuclear, or matrix types. The encapsulating materials must also have many specific requirements as the following: chemically inert; non-toxic; sterilized; stable from a physical-chemical point of view; mechanically resistant; must not release impurities or other residues [1]. Microencapsulation processes can be classified into three categories physical, chemical, and physicochemical processes [45]. The physical methods include spray drying, spray-chilling, rotary disk atomization, fluid bed coating, stationary nozzle co-extrusion, multi orifice-centrifugal process, submerged nozzle co-extrusion, pan coating, air suspension coating, and centrifugal extrusion. Physicochemical processes refer to the formation of the microcapsule/microsphere shell from a preformed polymer involving processes such as ionotropic gelation, polyelectrolyte complexation, coacervation, phase separation, and solvent removal [75]. Spray drying is the most common technology used in the food industry to microencapsulate bioactive food ingredients [27]. Optimization in encapsulation is necessary. Many optimization models such as RSM based on CCD and swarm intelligence algorithms were successfully employed to optimize the ultrasonic-assisted. Encapsulates should show acceptable hygroscopicity, suitable solubility, good encapsulation efficiency, and bioavailability for efficient drug delivery to the target in the system. The selection of more-stable microcapsules will delay the release of the encapsulated compound [36]. Further physicochemical characterization of microencapsulates can be obtained by analyzing morphological investigation in scanning electron microscopy (SEM), transmission electron microscopy (TEM), analyzing particle size distribution in dynamic light scattering (DLS) and zeta analyzer, analyzing structural distribution in FTIR, etc. [77]. For the *in silico* study of encapsulates formation, molecular docking and simulation are also performed by many researchers which illustrates the possible molecular bonding and the whole scenario of complex formation. Simulation can also predict the drug delivery process and possible bioactivities in the target. It can also predict the possible disadvantages of the complex compounds during the drug delivery process [30]. *In vivo*, *in vitro* and *in silico* bioavailability can also be performed to study the possible accessible matters and possible bioactivities in the target specified.

1.10 Enrichment of phytochemicals of a food system

The enrichment of phytochemicals in a food system enhances its functional properties. Bioactive components like anthocyanin, carotenoids, vitamin C, vitamin E, quercetin, phenolic acids, etc., have been added additionally, that affects the original qualitative attributes of the food system and enhances the additional health-beneficial properties [62]. Enrichment of phytochemicals can be done by directly incorporating the phytochemical-rich product/compound/extract into any favorable food system in desired dose/concentrations [24]. Enrichment of some phytochemicals with antioxidant properties also enhances the shelf life of the food model. A toxicity study is important before performing a sensory evaluation of any product in person to avoid any kind of toxicities from the developed food product [62]. Nowadays, many food industries are inspired by functional foods and therefore, focus more on producing various food products with maximum recovery of their antioxidant properties. Many kinds of research on the incorporation of phytochemicals in food models like extruded foods, beverages, nachos, bakeries, ready-to-cook soup/vegetable mixes, etc. are in huge trend nowadays. Incorporation of phytochemicals in food model should not exhibit undesirable quality of the food model. Along with product development, a study on detailed sensory attributes is important to meet customer satisfaction and launch a profitable food industry [28].

1.11 Hypothesis

The hypothesis of the research work is the phytochemicals enriched food product developed from bhimkol (*Musa balbisiana*) banana blossom will exhibit:

1. Antidiabetic property
2. Antioxidant activity
3. Controlled release of quercetin in intestine by surviving stomach digestion, that will provide controlled bioactivities in intestinal cells
4. Higher bioavailability of quercetin by encapsulation
5. Good customer acceptability based on sensory attributes

1.12 Gap of research

The major phytochemicals present in banana blossoms can be extracted and can be encapsulated to provide directly to the human diet or by incorporation in some food models. Although banana blossoms have been consumed as a food source since ancient times, their consumption level is low because of their astringent flavor, lack of awareness of their edibility, and their medicinal values [6]. Therefore, it is very imperative to encourage highly utilizing the unexplored food commodity in terms of environmental factors and health perspectives.

1. Mostly banana blossoms are usually discarded and underutilized
2. Less cultivation of bhimkol blossom because of seeds content in fruit
3. Dislike astringent flavor of blossom by major population
4. Lack of awareness of its edibility
5. Only a few studies have been reported in the bhimkol blossom
6. Lack of awareness of its high nutritional value, phytochemical compounds, and its health beneficial properties
7. Lack of awareness between poisonous and non-poisonous variety of banana blossom
8. There are almost negligible study in *in vivo* toxicity study of bhimkol blossoms

For these reasons, the present research is to bring out other applications for these by-products, to make them more useful to the economy, by conducting a detailed study on the nutritional and phytochemical compositions of banana blossoms grown along with their health benefits.

1.13 Objectives

The present study was conducted in six divided technical objectives:

i. To identify the phytochemical contents of bhimkol (*Musa balbisiana*) banana blossom and optimization of their extraction using supercritical fluid extraction (SCFE) and ultrasound assisted extraction (UAE)
ii. To model nachos from bhimkol blossom by using an artificial intelligence approach
iii. To purify and characterize the major phytochemicals from bhimkol blossom
iv. To study encapsulation of purified phytochemicals and its *in vitro* bioavailability
v. To develop phytochemical enriched food product by incorporation of encapsulated phytochemical compounds and its properties
vi. To study antidiabetic properties of phytochemical extract of bhimkol blossom

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