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Microencapsulation techniques used for underutilized fruits of western Ghat: An overview

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Abstract

Fruits are the nature's gift to mankind, they are not only delicious and refreshing, but also nutritionally rich and supplementing the daily diet of the people. Western Ghats, one among eight "hottest hot-spots" of biodiversity in world harbor many wild, unexploited and minor fruits which are edible and unfamiliar to large proportion of the global population. Some of these fruit crops available in western Ghat are Underutilized edible fruits are important source of food and income for rural communities. Underutilized fruits are therapeutic in nature and used to treat wide array of diseases including chronic diseases. In the last three decades, increased urbanization and deforestation for agricultural land use has led to destruction of valuable plant species including fruit yielding plants. As a result, substantial decrease in the consumption and utilization of underutilized edible fruits has been noticed. The present article describes 45 fruits that are edible and prominent in the Western Ghats region of Southern India. Encapsulation of fruits preserve the organoleptic profile of the product until use and this can ensure the high quality and commercial value of the product. In this review article, several encapsulation techniques that are used commercially or are being applied in the food industry are discussed. This includes spray drying, spray cooling, spray chilling, fluid bed, extrusion, co-crystallization, co-acervation, molecular inclusions and liposome.

Keywords: Western Ghats, under-utilized fruits, fruits, encapsulation techniques

Introduction

The Western Ghats region of Indian subcontinent is very rich in diverse edible fruit yielding plant species. The Western Ghats hills lay in the East Coast of Arabian seas and spread in six Indian states, namely Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala in a stretch of 1,600 km long and 40-60 km wide from North to South. The region has several mountain peaks, which hinder monsoon winds resulting in heavy rainfall in this region. The heavy rainfall and different temperature conditions allow several plant species inhabiting the region (Bawa and Kadur, 2005) [5].

The area is one of the biodiversity hotspots of the world and is home for 7,402 species of flowering plants, 1,814 species of non-flowering plants; it is likely that many undiscovered species live in the Western Ghats. Nayar *et al*., 2014 [37] reported that 11 fruit plant species were investigated for their nutritional food value and medicine from Western Ghats region of Maharashtra. The fruits are rich in sodium, potassium, magnesium, iron, calcium, phosphorus, etc. (Sasi and Rajendran, 2012) [51].

The Western Ghats (Sahyadris) comprise the Malabar province of the Oriental realm, running parallel to the west coast of India from 8 N to 21 N latitudes, 73 E to 77 E longitudes, traverses through the states of Maharashtra, Goa, Karnataka, Tamil Nadu, and Kerala over a 1600 km distance at an average width of 200 km). These mountain chains are considered as the one of the hottest mega diversity hotspot of the world which directly and indirectly supports the livelihoods of over 200 million people. Out of the 15,000 species of angiosperms reported from India, 1000 species are used directly or indirectly as food stuff (Arora and Pandey 1996) [2] and from the Kerala part of the Western Ghats itself, a total of 5094 species of flowering plants were reported (Sasidharan, 2011) [45, 52].

There are more than 60 underutilized edible fruits available in entire Western Ghats region. More recently, (Jadhav *et al*., 2015) [22] reported 159 underutilized edible plants from the Northern Western hats of Maharashtra, of which 77 fruit bearing plant species are edible and most fruits are consumed during January July.

According to (Kumar and Shiddamallayya, 2016) [27, 66], forest region of Hassan district of Southern Western Ghats has 75 underutilized edible fruit species belonging to 40 families and

60 genera.

The underutilized edible plants (WEPs) are being used on the basis of traditional ecological knowledge (Arenas and Scarpa 2007) [1], a crucial source of micronutrients, and also contribute to livelihoods and are available during times of drought or conflict driven famine (Enfors and Gordon 2008; Muller and Almedom 2008) [14, 32] especially in India and Bangladesh. (Grivetti and Ogle 2000) [20] reported that more than 7000 species of underutilized edible plants are used as food at some stages in the human history. Among the WEPs, the edible fruit bearing species form one of the most important local survival strategies and its uses are well depicted in ancient literature such as Vedas, Puranans and Upanishads. In Qur'an, the dates and figs are regarded as the heavenly fruits of God. In Charaka Samhitha, Acharya Charaka had explained the qualities of 70 edible fruits under Phalavarga in enormous diversity of underutilized edible fruiting plants and the data is highly scattered and its usage is highly restricted to tribal community (Radhakrishnan *et al*. 1994) [45].

In recent years, the available of these fruits has decreased due to change in land use pattern, human disturbance and unsustainable exploitation. Thus, effort attempts were made with the objective of recording availability of these species, proximate analysis and their on farm and off farm conservation.

Underutilized fruits of Western Ghats

The present article describes some of the important underutilized fruits of the Western Ghats, A list of 45 fruits has been listed out that are edible, but the list is by no means complete. Information is provided for the rare fruits that are consumed by the tribal and rural communities. Although people consume these fruits freshly, in certain occasions the juice is taken out from the rind, rind is sundried and used as a souring agent as spice for the preparation of beverages and typical south Indian cuisines. Seeds of some Clusiaceae members such as Garcinia indica and Garcinia gummi-gutta yield high oil, which is known to comprise potential therapeutic properties. Commercially, butter extracted from these fruits are used for producing cosmetics and functional foods, however, traditionally these fruits are utilized for esculent, medicinal and cosmetic purposes as shown in Fig.1.

Fig 1: Fruits of Garcinia species: A.G. morella, B.G. pushpangadaniana, C.G. talbotii, D.G. travancorica, E.G. rubroechinata, F.G. imberti, G.G. wightii, H.G. indica, I.G. xanthochymus, J.G. gummi-gutta var. gummi-gutta, K.G. gummi-gutta var. conicarpa, L.G. gummi-gutta var. Papilla

Table 1: Western Ghat fruits and mode of consumption and utilization

Sl. No.	Botanical Name	Local name	Family	Mode of consumption and utilization	References
1	Anacardiaceae	cashew	*Anacardium occidentale* L.	Jam, jelly, vinegar, pectin, nonalcoholic and alcoholic beverages	Chakraborty *et al*., 1977; [8, 10] Mohanty *et al*., 2006 [31]
2	Anacardiaceae	Chironji	*Buchanania cochinchinensis* (Lour.) M.R. Almeida	Consumed fresh, seeds- raw or cooked, oil is extracted from the seeds	Kumar *et al*., 2012 [27, 66]
3	Anacardiaceae	marking nut tree	Semecarpus anacardium Blanco	Dried fruits are consumed	Jadhav *et al*., 2015 [22]
4	Anacardiaceae	Bilati Aamraa	Spondias dulcis Parkinson	Consumed fresh, pickles	Bhat and Rajanna, 2016 [6]
5	Annonaceae	Soursop	*Annona muricata* L	Ripe fruit consumed, fermented beverage	Minh, 2015 [30]
6	Apocynaceae	Bush plum	*Carissa spinarum* L.	Consumed fresh, pickles, and jams are prepared	Fatima *et al*., 2013; [16] Chauvan *et al*., 2015
7	Arecaceae	Wild date palm	Phoenix sylvestris (L.) Roxb.	Consumed fresh Dried fruits consumed	Jadhav *et al*., 2015 [22]
8	Berberidaceae	Nilgiri Barberry	*Berberis tinctoria* Lesch	Consumed fresh	Nayagam *et al*., 1993 [36]
9	Boraginaceae	Indian Cherry	Cordia dichotoma G. Forst.	Consumed fresh, pickled	Valvi and Rathod, 2011 [64]
10	Cactaceae	Prickly pear	Opuntia dillenii (Ker Gawl.) Haw.	Consumed fresh	Nayagam *et al*., 1993 [36]
11	Clusiaceae	Brindleberry, Malabar tamarind, and Kudam Puli (pot tamarind)	*Garcinia gummi-gutta* (Linn.) Robson	Fruit and juice are used as souring agent and butter from rind is prepared	Naveen and Krishnakumar, 2012; [35, 56] Namera *et al*., 2014 [33]
12	Rubiaceae	Dekamella-gum gardenia, Gummy cape jasmine, Cumbi-gum tree.	*Gardenia gemmifera* L.f	Consumed fresh	Sivakamasundari *et al*., 2015 [57]
13	Clusiaceae	Kokam	Garcinia indica (Thouars) Choisy	Consumed fresh, Juice and wine	Bafna, 2012 [3]; Naveen and Krishnakumar, 2013 [35, 56]; Swami *et al*., 2014
14	Clusiaceae	Mysore Gamboge.	Garcinia xanthochymous Hook	Consumed fresh, Wine	Rai *et al*., 2010 [46]; Mahesh *et al*., 2016 [28]
15	Dilleniaceae	Karmal, Dog Teak, Dillenia, Nepali elephant apple	Dillenia pentagyna Roxb.	Consumed fresh	Sundarapandian and Swamy, 1999 [60]

16	Elaeagnaceae	Wild olive	Elaeagnus conferta Roxb.	Consumed fresh	Valvi and Rathod, 2011 [64]; Patil *et al*., 2012
17	Elaeagnaceae	Jew's plum	Elaeocarpus tectorius (Lour.) Poir	Consumed fresh	Nayagam *et al*., 1993 [36]
18	Moraceae	Wild jack	Artocarpus hirsutus Lam.	Consumed fresh and pickled	Vinay *et al*., 2014 [67]
19	Moraceae	Jackfruit	Artocarpus gomezianus Wall. Ex Trecul.	Consumed fresh and juice, used as spice	Krishnamurthy and Sarala, 2013; [26] Sarala and Krishnamurthy, 2014 [26]
20	Myrtaceae	Gooseberry	Rhodomyrtus tomentosa (Alton) Hassk.	Consumed fresh	Nayagam *et al*., 1993 [36]
21	Myrtaceae	Karinjara, Kunta Nerale	*Syzygium caryophyllatum* (L.) Alston	Consumed fresh and wine	Shilpa and Krishnakumar, 2015 [35, 56]
22	Myrtaceae	Malabar plum	Syzygium jambos (L.)	Consumed as fresh juice and wine	Dhanabalan *et al*., 2014 [12]
23	Myrtaceae	Gudda nerale	Syzygium zeylanicum Altson	Consumed fresh and wine	Shilpa and Krishnakumar, 2015 [35, 56]
24	Oxalidaceae	Bilimbi	*Averrhoa bilimbi* L.	Cooked and pickled	Bhat and Rajanna, 2016 [6]
25	*Oxalid aceae*	Star fruit	*Averrhoa carambola* L	Consumed fresh, juice and wine	Napahde *et al*., 2010 [34]; Bhat *et al*., 2011; [6] Dasgupta *et al*., 2013 [10]; Paul and Sahu, 2014 [41]; Bhat and Rajanna, 2016 [6]
26	Passifloraceae	Passion fruit	Passiflora edulis Sims.	Consumed fresh, juice is prepared	Pruthi and Girdhari, 1955
27	Phyllanthaceae	Kebella	*Aporosa cardiosperma* (Gaertn) Merr.	Ripe fruits consumed	Bhat and Rajanna, 2016 [6]
28	Phyllanthaceae	Amla	*Phyllanthus emblica* L.	Consumed fresh, jam, juice and wine are prepared	Nambiar *et al*., 2016; Peerajan *et al*., 2016 [42]
29	Rhamnaceae	Indian plum	*Ziziphus oenopolia* (L.) Mill	Consumed fresh	Jadhav *et al*., 2015 [22]
30	Rhamnaceae	Wine Jujube	Ziziphus jujube Mill.	Consumed fresh	Jadhav *et al*., 2015 [22]
31	Rhamnaceae	zunna berry	Ziziphus rugosa Lamk.	Consumed fresh, juice and dosa are prepared	Krishnamurthy and Sarala, 2011 [26]
32	Rosaceae	Raspberry	Rubus ellipticus Smith	Consumed fresh	Nayagam *et al*., 1993 [36]
33	Rosaceae	Black raspberry	*Rubus racemosus* Roxb	Consumed fresh	Nayagam *et al*., 1993 [36]
34	Rosaceae	Himalayan raspberry	Rubus rugosus Smith	Consumed fresh	Nayagam *et al*., 1993 [36]
35	Rubiaceae	Carray Cheddle, Coromandel Canthium, Honey-thorn	Canthium coromandelicum (Burm.)	Consumed fresh	Sambandan and Dhatchanamoorthy, 2012 [50]
36	Rubiaceae	Bakora	*Ixora coccinea* L	Consumed fresh	Jadhav *et al*., 2015 [22]
37	Rutaceae	Wood apple	*Aegle marmelos* (L.) Correa	Juice and wine	Pandaa *et al*., 2014
38	Rutaceae	Orange berry	Glycosmis Pentaphylla (Retz.) DC.	Consumed fresh	Valvi and Rathod, 2011 [64]
39	Rutaceae	Wild orange	*Toddalia asiatica* (L.) Lam.	Consumed fresh	Nayagam *et al*., 1993 [36]
40	Salicaceae	Kakkade, Mountain Sweet Thorn, Raan-tambut	Flacourtia montana J. Grahm.	Consumed fresh	Abhishek and Thangadurai, 2015
41	Salicaceae	Indian plum	Flacourtia indica (Burm. f.) Merr.	Consumed fresh	Valvi and Rathod [64], 2011; Jadhav *et al*., 2015 [22]
42	Sapindaceae	Koshimb, Kusumb	Schleicheraoleosa (Lour.)	Consumed fresh, shoots as vegetable	Valvi and Rathod, 2011 [64]
43	Sapindaceae	Spanish cherry, Bakul	*Mimusops elengi* L.	Consumed fresh	Valvi *et al*., 2011 [64]
44	Verbenaceae	Indradhana	*Lantana camara* L.	Consumed fresh	Venkatachalam *et al*., 2011a [66]

Microencapsulation is defined as a process in which tiny particles or droplets are surrounded by a coating or embedded in a homogeneous or heterogeneous matrix, to give small capsules with many useful properties. Microencapsulation can provide a physical barrier between the core compound and the other components of the product. It is a technique by which liquid droplets, solid particles or gas compounds are entrapped into thin films of a food grade microencapsulating agent. The core may be composed of just one or several ingredients and the wall may be single or double-layered (Shahidi and Han, 1993) [55].

The retention of these cores is governed by their chemical functionality, solubility, polarity and volatility. (Shahidi and Han, 1993) [55] proposed six reasons for applying microencapsulation in food industry: to reduce the core reactivity with environmental factors; to decrease the transfer rate of the core material to the outside environment; to promote easier handling; to control the release of the core material; to mask the core taste and finally to dilute the core material when it is required to be used in very minute amounts. In its simplest form, a microcapsule is a small sphere with a uniform wall around it. The material inside the microcapsule is referred to as the core, internal phase or wall, whereas the wall is sometimes called shell, coating, wall material or membrane. Practically, the core may be a crystalline material, a jagged adsorbent particle, an emulsion, a suspension of solids or a suspension of smaller microcapsules. Microencapsulation has many applications in food industry such as to protect, isolate or control the release of a given substance which is of growing interest in many sectors of food product development. Converting a liquid into a powder allows many alternative uses of ingredients. One of the largest food applications is the encapsulation of flavours (Shahidi and Han, 1993) [55].

Encapsulation techniques of food ingredients and the potential utilization of the technology in the food industry had been discussed in the literature by various authors (Torkamani *et al*., 2018) [63]. The application of encapsulation processes in the food industry includes some special considerations, primarily those concerned to the solvent and to the wall material which could be generally recognized as safe (GRAS).

Methods of encapsulation

The encapsulation can be produced by different methods (Ibrahim *et al.*, 2017 [21]; Fang, and Bhandari, 2010 [15]; Youngs, 1986) [68].

1. Physical process: spray drying; fluid bed coating, spray chilling, freeze drying extrusion and co-crystallization.
2. Physicochemical: solvent evaporating (organic phase separation), liposome entrapment, simple or complex coacervation (liquid phase separation).
3. Chemical process: interfacial polymerization, and molecular inclusion.

Microencapsulation tenchniques Spray drying

Spray drying is the most common microencapsulation technique used in food industry. Spray drying technique for producing encapsulated flavouring was discovered by A Boake Roberts in 1937, when acetone was accidently added to tomato puree which helped him to maintain colour and flavour of tomato powder during spray drying. Subsequently, spray drying has become the most important commercial process for making dry flavourings. Vitamins, minerals, colorants, fat and oil flavour, aroma compounds, oleoresins and enzymes have been encapsulated using this technique. It is an economical, as well as an effective method for protecting materials and is most widely employed, particularly for flavours for which specialized equipment is not required. For encapsulation purposes, modified starch, maltodextrin, gum or others are hydrated to be used as the carrier or wall material. The material for encapsulation is homogenized with the carrier material usually at a ratio of 1: 4. The mixture is then fed into a spray dryer and atomized with a nozzle or spinning wheel. Water is evaporated by the hot air contacting the atomized material. The capsules are then collected after they fall to the bottom of the drier (Gibbs, 1999) [17].

Spray chilling

In spray chilling, the material to be encapsulated is mixed with the carrier and atomized by cooled or chilled air as opposed to heated air used in spray drying (Risch, 1995) [65]. The outer material is usually vegetable oil in the case of spray cooling (45 to 122°C) or a hydrogenated or fractionated vegetable oil in the case of spray chilling (32 to 42°C). Frozen liquids, heat-sensitive materials and those not soluble in the usual solvents can be encapsulated by spray chilling / spray cooling. It is the least expensive encapsulation technology and is routinely used for the encapsulation of a number of organic and inorganic salts like ferrous sulfate, vitamin, mineral or acidulents as well as textural ingredients, enzymes, flavors and other functional ingredients to improve heat stability, delay release in wet environments, and/or convert liquid hydrophilic ingredient into free flowing powders.

Spray cooling

Spray cooling is called as ‘matrix’ encapsulation because the particles are more adequately described as aggregates of active ingredient particles buried in the fat matrix, while ‘true’ encapsulation is usually reserved for processes leading to a core/shell type of microencapsules. A matrix encapsulation process leaves a significant proportion of the active ingredient lying on the surface of the microcapsules or sticking out of the fat matrix, thus having direct access to the environment. Particles produced by a matrix encapsulation process generally release their entire content within a few minutes after being incorporated in the food. A non-negligible proportion of active ingredients can also be found on the surface of a core/shell type of microcapsule, but the bulk of the ingredient is encapsulated and much slower release kinetics are typically obtained. Even though the process does not lead to a perfect encapsulate, the properties obtained by spray cooling/ chilling are sufficient to achieve the desired delayed release of the ingredient in the actual application. However, a strong binding of the ingredient to the fat matrix can prevent the release of the ingredient even if the fat matrix is melted and/or damaged during processing. (Gouin, 2004) [19]. 4. A.

Extrusion

Extrusion microencapsulation has been used almost exclusively for the encapsulation of volatile and unstable flavors in glassy carbohydrate matrices. The main advantage of this process is the very long shelf life imparted to normally oxidation-prone flavor compounds, such as citrus oils, because atmospheric gases diffuse very slowly through the hydrophilic glassy matrix, thus providing an almost impermeable barrier against oxygen. Shelf lives of up to 5 years have been reported for extruded flavor oils, compared to typically 1 year for spray dried flavors and a few months for unencapsulated citrus oils. Carbohydrate matrices in the glassy states have very good barrier properties and extrusion is a convenient process enabling the encapsulation of flavors in such matrices (Zasypkin and Porzio, 2004) [69]. This process can be used for encapsulating nutraceuticals. These processes could, theoretically use glassy carbohydrates as shell material, such as fluidize bed coating, but extrusion remains the most suitable process for such shell materials. The basis of the process was developed by (Schultz *et al*., 1956) [53] and later improved by (Swisher, 1957) [62]. A lower temperature process is developed, in which a mass of potato starch, glycerol and water is processed and gelatinized in a twin screw extruder at about 100 °C. The mass is then cooled down and the bioactive formulation is injected in the last barrel, where the temperature should approximately be 50 °C.

The extruded ropes are cut into pieces and dried (Quellet *et al*, 2001) [44]. B. Centrifugal Extrusion Centrifugal extrusion is another encapsulation technique that has been investigated and used by some manufacturers. A number of food-approved coating systems have been formulated to encapsulate products such as flavorings, seasonings, and vitamins. These wall materials include gelatin, sodium alginate, starches, cellulose derivatives, gum acacia, fats, fatty acids, waxes, and polyethylene glycol. Centrifugal extrusion is a liquid coextrusion process utilizing nozzles consisting of a concentric orifice located on the outer circumference of a rotating cylinder i.e., the head.

The encapsulating cylinder or head consists of a concentric feed tube through which coating and core materials are pumped separately to the many nozzles mounted on the outer surface of the device. While the core material passes through the center tube, coating material flows through the outer tube. The entire device is attached to a rotating shaft such that the head rotates around its vertical axis. As the head rotates, the core and coating materials are co-extruded through the concentric orifices of the nozzles as a fluid rod of the core sheathed in coating material. Centrifugal force impels the rod outward, causing it to break into tiny particles. By the action of surface tension, the coating material envelops the core material, thus accomplishing encapsulation. The microcapsules are collected on a moving bed of fine- grained starch, which cushions their impact and absorbs unwanted coating moisture. Particles produced by this method have a diameter ranging from 150 to 2000 mm (Schlameus, 1995; Goud and Park, 2005) [54].

Fluidized bed coating

Fluidized bed technology is a very efficient way to apply a uniform layer of shell material onto solid particles. Interestingly, fluidized bed technology is one of the few advanced technologies capable of coating particles with any kind of shell material like polysaccharides, proteins, emulsifiers, fats, complex formulations, enteric coating, powder coatings, yeast cell extract, etc. Therefore, the controlled release possibilities are considerably more versatile with the fluidized bed technology than with any other technologies. Aqueous solutions of hydrocolloids such as gums and proteins, ethanolic solutions of synthetic polymers and melted fats/waxes have all been used as coating formulations in fluidized bed microencapsulation processes. Spray dried microcapsules can also be further coated by fluidized bed, with a fat layer in order to impart better protection and shelf life. The use of melted fats, waxes or emulsifiers as shell materials is a relatively new but very promising and interesting concept. In this technique solid particles are suspended in a temperature and humidity controlled chamber of high velocity air where the coating material is atomized (De Zarn, 1995) [11]. Optimal results are obtained with particle sizes between 50 and 500 microns. Particle size distribution should also be narrow. The amount of material that coats the particles is dependent on the length of time that the particles are in the chamber. This technique is applicable for hot-melt coatings such as hydrogenated vegetable oil, stearines, fatty acids, emulsifiers and waxes or solvent-based coatings such as starches, gums, maltodextrin (Tsutsumi, *et al* 1998; Matsuda, *et al.* 2001; Gouin 2004) [19, 29].

Liposomal entrapment

A liposome or lipid vesicle is defined as a structure composed of lipid bilayers that enclose a number aqueous or liquid compartments. They have been used for delivery of vaccines, hormones, enzymes and vitamins into the body. They consist of one or more layers of lipids and are nontoxic and acceptable for foods. Permeability, stability, surface activity and affinity can be varied through size and lipid composition variations. They can range from 25 nm to several microns in diameter, are easy to make, and can be stored by freeze-drying. Phospholipids make up the outer layer or layers of liposomes. The hydrophilic portion of the lipids is oriented towards the aqueous phase and the hydrophobic groups associate with the hydrophobic ones of other lipid molecules. Folding of the lipid sheet into a spherical shape forms a very stable capsule due to there being no interaction of the lipids with water Aqueous or lipid-soluble materials, but not both, are entrapped in these membranes. Liposomes can range from a few nanometers to microns. Food applications of liposomes in cheese making is well known (Kirby, 1991) [23]. The most common phospholipid in lectin, namely phosphatidyl choline, is insoluble in water and is isolated from soy or egg yolk. The composition of the phospholipids and the process used determine if a single or multiple layers are formed. Fatty acids also make up liposomes and their degree of saturation is dependent on the source. Animal sources provide more saturated fatty acids. They influence the transition temperature which is the conversion from a gel to the more leaky liquid form. Although sugars and large polar molecules cannot permeate through a liposome bi layer, small lipophilic molecules can. (Kim and Baianu *et al*., 1991) [24].

Lyophilization or freeze-drying

Lyophilization or freeze-drying is a process used for the dehydration of almost all heat sensitive materials and aromas. It has been used to encapsulate water-soluble essences and natural aromas as well as drugs. Except for the long dehydration period required (commonly 20 h), freeze-drying is a simple technique, which is particularly suitable for the encapsulation of aromatic materials. The retention of volatile compounds during the lyophilization is dependent upon the chemical nature of the system (Kopelman *et al.*, 1977) [25].

Coacervation

Coacervation, often called ‘‘phase separation,’’ is considered as a true microencapsulation technique, because the core material is completely entrapped by the matrix. This technique involves the precipitation or separation of a colloidal phase from an aqueous phase (Dziezak, 1988; Bakan, 1973) [13]. Both, simple and complex methods of coacervation can be used. In simple coacervation, a non-solvent or a more water-soluble polymer is used. The polymer competes for the solubility for gelatin protein solution by hydrophobic interaction. In complex coacervation, the capsule is formed by the ionic interaction of two oppositely charged polymers, commonly the positive charges on protein molecules and anionic macromolecules such as gelatin and gum arabic (Versic, 1988; Soper, 1995; Brazel, 1999) [7, 58, 65]. The complex coacervate is produced when the two opposite charges are neutralized with each other (Soper, 1995) [58].

Centrifugal suspension

Separation Centrifugal suspension is a more recent microencapsulation process. The process in principle involves mixing the core and wall materials and then adding them to a rotating disk. The core materials leave the disk with a coating of residual liquid. The microcapsules are then dried or chilled after removal from the disk. The whole process can take between a few seconds to minutes. Solids, liquids, or suspensions of 30 mm to 2mm can be encapsulated in this manner. Coatings can be 1–200 mm in thickness and include fats, polyethylene glycol (PEG), diglycerides, and other meltable substances. Since this is a continuous, highspeed method that can coat particles, it is highly suitable for foods. One application is to protect foods that are sensitive to or readily absorb moisture, such as aspartame, vitamins, or methionine (Sparks, 1989) [59].

Co-crystallization

Cocrystallization is a new encapsulation process utilizing sucrose as a matrix for the incorporation of core materials. The sucrose syrup is concentrated to the supersaturated state and maintained at a temperature high enough to prevent crystallization. A predetermined amount of core material is then added to the concentrated syrup with vigorous mechanical agitation, thus providing nucleation for the sucrose/ingredient mixture to crystallize. As the syrup reaches the temperature at which transformation and crystallization begin, a substantial amount of heat is emitted. Agitation is continued in order to promote and extend transformation/ crystallization until the agglomerates are discharged from the vessel. The encapsulated products are then dried to the desired moisture if necessary and screened to a uniform size. It is very important to properly control the rates of nucleation and crystallization as well as the thermal balance during the various phases (Rizzuto *et al*, 1984) [49].

Inclusion complexation

Molecular inclusion is another means of achieving encapsulation. Unlike other processes discussed, this technique takes place at a molecular level; â-cyclodextrin is typically used as the encapsulating medium. â-Cyclodextrin is a cyclic derivative of starch made up of seven glucopyranose units. They are prepared from partially hydrolyzed starch (maltodextrin) by an enzymatic process. The external part of the cyclodextrin molecule is hydrophilic, whereas the internal part is hydrophobic. The guest molecules, which are apolar, can be entrapped into the apolar internal cavity through a hydrophobic interaction (Pagington, 1986; Goud and Park, 2005) [18, 38]. This internal cavity of about 0.65nm diameter permits the inclusion of essential oil compounds and can take up one or more flavor volatile molecules (Dziezak, 1998) [13]. In this method, the flavor compounds are entrapped inside the hollow center of a maltodextrin molecule.

The major reasons for using the encapsulation are as follows (Re, 1998)

1. Securing the product from the surrounding conditions (temperature, moistur etc.). - Protecting the active ingredient against deterioration and limiting the evaporation (losses) of volatile material. -
2. Saving the environment from the hazards and toxic product to be more safely during its handling. -
   Dry handling by conversion of liquids and sticky solids to free flowing powders. - Masking of undesired properties of the active components, like taste and odour.

Conclusion

The Underutilized edible fruit species of the Western Ghats region serve as important component of the ecosystem of the area. Due to changes in land use, many of these valuable species are being removed and there is an urgent need to conserve these valuable underutilized plants. Studies on their nutritional and pharmaceutical importance, and efforts towards multiplication for value assessment for economical values attribution to the fruit products will contribute to cultivation of such species.

Flavor encapsulation is the key technology for flavor delivery in liquid and dry systems. Several different methods are available for producing the dried flavoring materials. These are freeze or spray drying, inclusion complexion, extrusion and coacervation. The selected type was depended on material of flavoring, equipment availability, budget, and applications.

Despite the wide range of encapsulated products that have been developed, manufactured, and successfully marketed in the pharmaceutical and cosmetic industries, microencapsulation has found a comparatively much smaller market in the food industry. The technology is still far from being fully developed and has yet to become a conventional tool in the food scientist repertoire for several reasons. Microencapsulation will certainly play an important role in this process, although it will always make an ingredient more expensive.

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