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MICROENCAPSULATION AND ITS UTILIZATION IN THE SECTOR OF HORTICULTURE : A REVIEW

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ABSTRACT

Microencapsulation today has evolved as a trustworthy tool in providing endurance to majority of the biologically active compounds which in general are not so stable and tends to degenerate very easily. In the field of horticulture, the horticultural commodities are stacked with such important active compounds. These compounds help in providing an advantageous output against various types of diseases and health related issues and ailments. But as mentioned majority of these important substances are not very rigid and extremely susceptible to changes in the environment, which may be physical, chemical or biological type. Therefore microencapsulation comes out as an important an protective tool where these targeted compounds called as the core materials are being covered or wrapped by the encapsulation process through outer coating called as the wall material and final product called as the microcapsules are delivered which have an increased availability and high effectiveness of the core materials inside. Therefore, the present paper is aimed in discussing about the process of microencapsulation in brief and to through a light toward some of the works of microencapsulation which has been successfully carried out in the discipline of horticulture.

***Keywords*:** coating, core, microcapsules, horticulture, study

INTRODUCTION

The activity or operation of microencapsulation can be described as one where tiny matters or liquid drips can be covered by another substance which are polymeric in nature thus producing a coated entity, which as a whole is very minute. These miniature substances as such are called as the microspheres or can also be termed as microcapsules (Corrêa-Filho *et al*., 2019). In the very activity of microencapsulation, the targeted compound which may be in any form of matter i.e. rigid, liquid or vapour is being separated to achieve a final material which is globular having the dimension ranging in micrometers. Here in the targeted material is guarded or protected by the help of a covering from the external situation (Nesterenko *et al*., 2013).

Thus as mentioned, in the phenomenon of microencapsulation the targeted material which in other words is also termed as the core material is required to be kept safe from the unwanted situation of the atmosphere outside and that is achieved by the another wrapping or covering material that acts as a representative for microencapsulation and is termed as the wall material (Corrêa-Filho *et al*., 2019). The stability and the features depicted by the microencapsulated particle is very much reliable upon different things. The particle which therefore will be formed after the process of microencapsulation can show variable characteristic property and it is very much based on the type of substance which is being used as the core, the kind of encapsulating material used and most importantly the category of process which is employed for undertaking the procedure of microencapsulation (Corrêa-Filho *et al*., 2019).

Today the exercise of microencapsulation is providing a very newer outlook towards research. The technique is finding different utilization in the variable sector of food industries. Not only this, has the usage of the process been found suitable in various cosmetic as well as pharmaceutical sectors. Furthermore, biomedical fields are also utilizing the process of microencapsulation to get the best output from it (Nesterenko *et al*., 2013; Dubey *et al*., 2009).

Wall Materials

The materials which are used for external wrapping or covering are called as the wall materials. These materials possess variable chemical build-up and different physicochemical abilities, which ultimately very much effects the productivity of the entire operation of microencapsulation. Hence it is very much required that the wall material should be very much carefully picked as because their selection directly reflects upon the balance of the final microencapsulated particles produced. Also, not only this but for how much time the inner targeted substance will withhold its characteristic property is also dependent upon the type of wall material chosen (Ray *et al*., 2016; Kang *et al*., 2019; Corrêa-Filho *et al*., 2019). Thus, the wall materials determine the amount of conservation and shielding it can provide it to the inner core material and helps in establishing the fate of the ultimate output particle. Different types of material which can be used for encapsulation of core material. Some of the common and frequently used substances are polymers of synthetic origin. Apart from these some natural compounds like waxes, fats substances obtained from animals and plants can be successfully incorporated (Nesterenko *et al*., 2013).

Core Materials

The substance which gets covered up during the process of microencapsulation are called as the core materials. These compounds which are targeted as the core can be a single unmixed substance or they can be concoction of various important items obtained from different parts of plants like trunk, blossoms, harvest, leaves or from remnant of agricultural type. These remnants can be subdivided into different categories like phenols and carotenoids which are bioactive substances, can be used. Furthermore, different types of vitamins and enzymes can be obtained (Rezende *et al*., 2018; Rodriguez-Amaya, 2018; Dias, 2017; Corrêa-Filho *et al*., 2019)

Techniques used in microencapsulation

Air suspension coating

In this very process a malleable floor containing warm or cold air is suspended with the targeted active core ingredient which is present in powder form. Thereafter the entire fluidized floor is sprinkled with the mixture containing the wall material (Kondo, 1989; Dziezak, 1988; Jackson and Lee, 1991). Then the drying of the sprinkled matter used as the coating material in the process takes up at a very faster rate. As a result of this, a covering layer having a dimension of certain extent is formed over the inner material when the wall material dries out. The dimension or the depth of the wall material thus formed is dependent upon the time duration for which it is being sprinkled upon. The most popular types of the coating materials which are used for the purpose are waxes, sugar, dextrin's etc. (Kondo, 1989, Dziezak, 1988; Jackson and Lee, 1991). This process is restricted to the final output of minimum size of 100 µm.

Spray drying

The process of spray drying is an uninterrupted event where the commencing material at liquid state is transformed in dehydrated powdered form by the process of dehydration. Spray drying in general is popular method of moisture removal which also forms incessant covering around the core material. The admixture which may be in the form of emulsion or solution, having both the covering and the inert material is sprinkled over a jet of hot air. Spray drying is used in removal of the water at a very speedy rate, as compared to different other process of dehydration. As a result of this the moisture from the solution gets disappeared immediately and lefts a powdered output. The process because of its comparative low cost of investment is widely used in various firms of variable sectors (Nesterenko *et al*., 2013).

Freeze drying

Freeze drying is another technique where the mixture comprising of the outer wall and the inner core substance is chilled at a temperature lower than -40^{0}C and thereafter its drying is carried out at pressure of lower range under the process of sublimation. This mentioned process or technique is quite easy and is very reliable for undertaking microencapsulation of naturally occurring category of compounds which otherwise are very much delicate to the presence of oxygen and high temperature. The technique of freeze drying thus helps in maintaining various categories of naturally derived plant extracts or products which are beneficial to us in one way or the other. This is because the procedure is carried out by implementation of cold condition and also oxygen is discarded while carrying out the operation. Under this type of technique different targeted compounds for example carotenoids and phenols are preserved (Fang and Bhandari, 2010; Ozkan *et al*., 2019; Corrêa-Filho *et al*., 2019).

Multi-orifice centrifugal extrusion

This operation or technique of microencapsulation is used to coat targeted compounds which are mainly liquid in nature or rigids having certain viscosity. Different types of coating materials can be employed for the purpose. In the process different inner materials like vitamins, proteins as well as variable wrapping materials like lipids, caseins and gums are flushed through different suckle channels inside a revolving noodle which comprises of multiple shafts in it (Dziezak, 1988; Jackson and Lee, 1991). Now the process of microencapsulation is stared with to get the desired encapsulated materials in stable form. When the noodle or the chamber starts revolving the spoke of the targeted compounded coated with the wall material comes out of the minute openings present in the noodle which gets shattered at the finish, which leads to formation of a globular shaped final encapsulated particle (Bakan, 1978; Jackson and Lee, 1991).

Coacervation

In this process the division between liquids of two different aspects inside a colloidal mixture of aqueous type happens. The one type of the liquid out of the two is very much abundant with the polymer and the other liquid type lacks in its quantity. The differentiation between both the liquid types can be achieved by varying the temperature, strength of the ions, pH and mixing capability of the medium to be dissolved (Moayyedi *et al*., 2018; Castro-Rosas *et al*., 2017; Corrêa-Filho *et al*., 2019). The process of coacervation is further subdivided into two categories and both of them are equally useful for the microencapsulation technique. This technique is termed as of simple type when it is carried in the liquid of aqueous type and the compound for covering is a single type polymer. On contrary to this the complex type process is where the wall compounds which are antagonistically charged gets to relate with each other which ultimately results in the distinguishment of the liquid phases because of the macromolecules exhibiting electrostatic inclination amongst each other (Corrêa-Filho *et al*., 2019).

Extrusion

The process of extrusion used for microencapsulation resembles itself to the method of spray drying. Under the technique here, both the material i.e. one used for coating and another to be coated is mixed with each other. Thereafter it is protruded out by a die in the presence of elevated pressure situation. The technique is very much in demand but in comparison to spray drying it lacks behind (Reineccius, 1989; Jackson and Lee, 1991). Various substances can be used to be employed as wall and core materials for the process of extrusion. In a very distinctive approach of the process a solution of flavour items acting as the core materials are mixed with starch at a temperature of 120^0C and it is extruded in isopropanol having a very low temperature. Due to the action of isopropanol present at low temperature the mixture gets converted from liquid to solid state and the unwanted surplus oil (flavour) is removed of. It has been found that the flavour particles which are being coated by the process have a better keeping life as compared to particles where no encapsulation has been carried on (Jackson and Lee, 1991).

Microencapsulation in horticulture

Anthocyanin the principle component of black raspberry was coated by the help of gum arabic and gelatin. Thereafter coacervation was used to develop the microcapsules. The capsules thus obtained from the study had a globular appearance and a comparatively even exterior. Storage study was made and the experiment showed that the microcapsules were able to reserve 36% of anthocyanin after two months of time (Shaddel *et al*., 2018).

Aswathy *et al.* (2019), studied microencapsulation of cherry tomato powder coated with maltodextrin as the wall material. During their study they carried several variations with respect to the physical and chemical conditions during drying at a spray dryer. Out of the several variations and combinations it was found that when the inlet temperature during the feed of the mixture was kept at 140^0C following with the flow of the solution @ 6ml/min and where maltodextrin at a concentration of 20% was used for the purpose of coating was found to be the best maintaining several desired attributes.

Pure carrot juice was encapsulated by utilizing maltodextrins, Gum Arabic and combination of both of them at different concentration as the coating material. Therefore, in this study conducted by Janiszewska-Turak *et al*. (2017) it was observed that out of the three materials used for coating gum Arabic was the finest one, maintaining good amount of carotenoid content.

In the work carried out by Pajaro Castro *et al*. (2017) the technique of microencapsulation was utilized to encapsulate the pulp of the fruit mango. Maltodextrin was used as the wall material for coating of the mango pulp. Thereafter the operation of spray drying was preformed to carry out the microencapsulation process. Spray drying helps in yielding desired type of encapsulated particles, coated properly with the wall materials. The drying process here provided round shaped proper microencapsulated entity. From there study it was found that spray drying helped in providing a chemical balance and maintained other parameters of the fruit. Most importantly it was observed that by the process of microencapsulation the Vitamin C retention increased to 65%.

In another study conducted by Dima *et al*. (2016) the essential oil of the coriander was microencapsulated by the utilization of various wall materials and incorporation of spray drying as for the operation process of microencapsulation. From their study the findings were that, the essential oil which were coated by alginate, chitosan and combination of chitosan and alginate and combination of inulin and chitosan were very much impervious to various fluctuations of acid and base variation and temperature changes and also the oil from these encapsulated particles were liberated at a moderate rate.

In the experiment done by Narayanan *et al*. (2018) microencapsulation was carried out where the anthocyanin pigment from the extract of amaranthus plants were targeted and was used as the core material. With respect to coating of the targeted core compound, maltodextrin was utilized to act as the wall material. Anthocyanin is one such water-soluble pigment which is very much vital for the human health as possessing significant antioxidant properties. Therefore, the study was taken to preserve the pigment through microencapsulation. For carrying of encapsulation of the selected anthocyanin pigment extract, the process of spray drying was employed. From the study it was revealed that the anthocyanin which were coated with equal amount of maltodextrin, helped in better preservation of the targeted compound and the colour was also improved.

Maltodextrin was used to coat the admixture of cinnamon extract which were then spray dried at different changing bay temperatures and at dissimilar feeding velocity. From the study carried out by Santiago-Adame *et al*. (2015) it was concluded that the microcapsules of cinnamon which were obtained by the inlet or bay temperature of 160^0C and as well as that of 180^0C where it was used with the combination of the feeding velocity of insertion of the suspension inside the drum for drying, at 10ml of mixture per minute was observed to be most suitable.

Sneha, (2016) did the work on microencapsulation of jamun powder through the help of spray drying method where maltodextrin was used as the coating element. After preparation of the encapsulated particles of the jamun powder they were prepacked in packets of laminated aluminuim foil and storage studies were conducted over a period of three months of duration. The layout of the study was done in such a way that for preparation of the encapsulated particles, multiple changes in the physical attributes were done. From the study, ultimately it was documented that the jamun microcapsules which were produced by maintaining the temperature of inlet at 170^0C, with a speed of 5ml/min of transferring the suspension solution to the drum and utilization of maltodextrin for covering up at an amount of 30% was observed to be the most suitable form of combination to produce the desired microencapsulated particle.

Freeze drying and spray drying were used to undertake the process of microencapsulation for doing the encapsulation of phenol extract from the five-star fruit. For the experiment maltodextrin was used as the wall material for covering up. After the fulfillment of the study done by Saikia *et al*. (2015) it was obtained that the microcapsules which were produced by employment of freeze drying showed the proficiency of 78-97%.

Microencapsulation of phenolic extract of plum fruit was done by using spray drying technique by Li *et al*. (2017). In the study combination of maltodextrin, beta-cyclodextrin and arabic gum was used as the coating or the wall material at the ratio of 7:2:1. Phenol is a very important content of fruits and vegetables which has got the strong capability in neutralizing the free radicals produced inside our body. The experiment, here thus targeted the preservation of the phenolic content of the fruit for a considerable period of time. The study after the completion of the experiment showed that the microcapsules of the plum fruit thus produced was able to maintain their phenolic content to as high as of 85% even after accomplishment of two months of storage time.

In a study three carrier particles i.e. isolate from whey protein, isolate from pea protein and maltodextrin was used for microencapsulation of extricates of grape marc and the dehydration was carried through spray drying method. The results of the experiment showed that, with respect to the drying yield, the compound maltodextrin for coating was the best. However, considering for long term storage through a period of six months, maximum anthocyanin maintenance was observed by the microcapsules coated with isolates from pea protein, enduring a dropping of only 20% (Moreno *et al*., 2018).

Citrulline extract from the skin or peel of the watermelon fruit was being encapsulated by the help of spray drying. The study was undertaken by Baron *et al*. (2018) where they used pectin for coating or covering the selected citrulline compounds. Citrulline is basically amino acid which is of the non-essential category, however the compound is a potent source exhibiting antioxidant potential, which benefits us. But the problem associated with the compound is that it is not very much stable in the presence of light and temperature. Therefore, encapsulation of the compound in the study helped in increasing its effectiveness and also from the experiment it was suggested that for citrulline, pectin can be used as a suitable wall material, because the microcapsules depicted proper dimensions.

Extracts from vanilla obtained naturally and synthetically were microencapsulated using protein concentrate of whey by the help of spray drying method. This study was conducted by Calva-Estrad *et al*. (2018) where they found that the microcapsules which were formed by the synthetically obtained extracts of vanilla, documented better confinement of the active ingredient which is vanillin during the time of storage.

Mixture of sodium alginate, chitosan and sodium tripolyphosphate was used as the wall material for coating of the carotenoid content of the kabocha pumpkin. The study was performed by Mulyadi *et al*. (2017) where they targeted to preserve the mentioned core material used in the study. Carotenoids though are present in a wide array of fruits and vegetables, but they are very much prone to loss. The carotenoids get easily affected due to oxygen and are very much photosensitive in nature. Therefore, in this study efforts were made towards the better utility of the compound. From the study it was obtained that the microcapsules of carotenoid provided a superior result. Also, the various other attributes associated to the compound were at a good state.

The study of Pasrija *et al*. (2015) emphasized on polyphenols of tea, as because these compounds possesses a tremendous benefit towards our health because of their many functional and nutraceutical properties. However, these compounds are very much thermo sensitive and gets readily effected in presence of alkaline pH situation. Therefore, the study aimed the microencapsulation of extracts of green tea by utilizing β-cyclodextrin, maltodextrin and combination of the former a later as the wall materials for coating. For carrying out the operation of microencapsulation, both the techniques of freeze drying and spray drying was employed. From the study it was seen that the microcapsules obtained from freeze drying technique had good activity regarding the antioxidants and efficiency of encapsulation was also high. As compared to the coating material the maltodextrin was satisfactory as it yielded better output. Thereafter microcapsules obtained through coating from maltodextrin and produced from both spray drying and freeze drying were embraced inside a food item i.e. bread to study the differences compared to the standard. Finally, it was observed that the breads which were embraced with the microcapsules of green tea extract had a preferable taste and showed good colour characteristic.

CONCLUSION

Horticultural sector has many health benefitting constituents having crucial functional and antioxidant abilities which can be properly covered up by suitable wall materials through this process. This would result in increasing their effectiveness and their serviceable life would be amplified as microencapsulation helps in safeguarding the targeted compounds or the core material from all sorts of wear and tear from various reactions and gives a shielding from the environmental abnormalities. Although it can be seen that perseverance of several active ingredients from numerous horticultural plants has been achieved by utilization of microencapsulation, but still plenty of works and research has to be carried out further in accomplishing many more success steps for securing the vital components obtained from important substances.

REFERENCES

Aswathy, S.; Suresha, G.J.; Sneha, N. and Sadananda, G.K. (2019). Microencapsulation of lycopene rich cherry tomato powder using spray drying. *Int. J. Chem. Stud.;* 7(1): 2270-2277.

Bakan, J.A. (1978). Microencapsulation. In: Peterson, M, S. and Johnson, A.H. (Eds). Encyclopedia of food science. Westport, CT: Avi Publishing Co.; pp. 499-507.

Barón, R.D.; Vargas, M.F.V.; Gamero, G.Q. and Carvajal, M.X.Q. (2018). Microencapsulation of citrullline extract from watermelon (*Citrullus lanatus*) rind by spray drying using response surface methodology (Rsm). International Conference on Nutritional Science and Food Technology. July 02-03, 2018 Rome, Italy.

Calva-Estrada, S.J.; Mendoza, M.R.; García, O.; Jiménez-Fernández, V.M. and Jiménez, M. (2018). Microencapsulation of vanilla (*Vanilla planifolia* Andrews) and powder characterization. *Powder Technol*.; 323: 416–423.

Castro-Rosas, J.; Ferreira-Grosso, C.R.; Gómez-Aldapa, C.A.; Rangel-Vargas, E.; Rodríguez-Marín, M.L.; Guzmán-Ortiz, F.A. and Falfan-Cortes, R.N. (2017). Recent advances in microencapsulation of natural sources of antimicrobial compounds used in food—A review. *Food Res. Int*.; 102: 575–587.

Corrêa-Filho, L.C.; Moldão-Martins, M. and Alves, V.D. (2019). Advances in the Application of Microcapsules as Carriers of Functional Compounds for Food Products. *Appl. Sci*.; 9: 571.

Dias, D.R.; Botrel, D.A.; Fernandes, R.V.D.B. and Borges, S.V. (2017). Encapsulation as a tool for bioprocessing of functional foods. *Curr. Opin. Food Sci*.; 13: 31–37.

Dima, C.; Patra¸scu, L.; Cantaragiu, A.; Alexe, P.; Dima, S. (2016). The kinetics of the swelling process and the release mechanisms of Coriandrum sativum L. essential oil from chitosan/alginate/inulin microcapsules. *Food Chem.*; 195: 39–48.

Dubey, R.; Shami, T.C. and Bhasker Rao, K.U. (2009). Microencapsulation technology and application. *Defence Sci. J.*; 59: 82-95.

Dziezxak, J.D. (1988). Microencapsulation and encapsulated ingredients. *Food Technol.*; 42: 136-151.

Fang, Z. and Bhandari, B. (2010). Encapsulation of polyphenols—A review. *Trends Food Sci. Technol.*; 21: 510–523.

Jackson, L.S. and Lee, K. (1991). Microencapsulation and the food industry. Lebensm.-Wiss.u.-Technol.; 24: 289-297.

Janiszewska-Turak, E.; Dellarosa, N.; Tylewicz, U.; Laghi, L.; Romani, S.; Dalla Rosa, M. and Witrowa-Rajchert, D. (2017). The influence of carrier material on some physical and structural properties of carrot juice microcapsules. *Food Chem.*; 236: 134–141.

Kang, Y.-R.; Lee, Y.-K.; Kim, Y.J. and Chang, Y.H. (2019). Characterization and storage stability of chlorophylls microencapsulated in different combination of gum Arabic and maltodextrin. *Food Chem.*; 272: 337–346.

Kondo, A. (1989). Microcapsule processing and technology. New York, NY: Marcel Dekker, Inc.; pp. 142-153.

Li.;Y, Y.; Tang, B.; Chen, J. and Lai, P. (2017). Microencapsulation of plum *(Prunus salicina* Lindl.) phenolics by spray drying technology and storage stability. *Food Sci. Technol.*; 38(3): Campinas July/Sept.

Moayyedi, M.; Eskandari, M.H.; Rad, A.H.E.; Ziaee, E.; Khodaparast, M.H.H. and Golmakani, M.-T. (2018). Effect of drying methods (electrospraying, freeze drying and spray drying) on survival and viability of microencapsulated Lactobacillus rhamnosus ATCC 7469. *J. Funct. Foods.*; 40: 391–399.

Moreno, T.; Cocero, M.J. and Rodríguez-Rojo, S. (2018). Storage stability and simulated gastrointestinal release of spray dried grape marc phenolics. *Food Bioprod. Process.*; 112: 96–107.

Mulyadi, N, M.; Widyaningsih, T.D.; Wijayanti, N.; Indrawati, R.; Heriyanto, and Limantara, L. (2017). Microencapsulation of Kabocha Pumpkin Carotenoids. *Int. J. Chem. Eng.;* 8(6):381-386.

Narayanan, M.; Shanmugam, S. and Suresh, P.M. (2018). Physical properties of microencapsulated anthocyanin obtained by spray drying of Red *Amaranthus* extract with maltodextrin. *Mal. J. Nutr.;* 24(1): 139-147.

Nesterenko, Alla and Alric, Isabelle and Silvestre, Françoise and Durrieu, Vanessa (In Press: 2013) Vegetable proteins in microencapsulation: a review of recent interventions and their effectiveness. Industrial Crops and Products, 42: 469-479.

Ozkan, G.; Franco, P.; De Marco, I.; Xiao, J. and Capanoglu, E. (2019). A review of microencapsulation methods for food antioxidants: Principles, advantages, drawbacks and applications. *Food Chem.*; 272: 494–506.

Pajaro Castro, N.P.; Conde, C.G.; Alarcón, M.E.T.; Fortich, M.D.R.O.; Castro, E.J.P. and Mendez, G.L. (2017). Microencapsulation of pulp of *Mangifera indica* l. by spray drying and antioxidant activity. *Int. J. Pharm. Pharm. Sci.;* 9 (12): 181-185.

Pasrija, D.; Ezhilarasi, P.N.; Indrani, D. and Anandharamakrishnan, C. (2015). Microencapsulation of green tea polyphenols and its effect on incorporated bread quality. *LWT Food Sci. Technol.*; 64: 289–296.

Ray, S.; Raychaudhuri, U. and Chakraborty, R. (2016). An overview of encapsulation of active compounds used in food products by drying technology. *Food Biosci.*; 13: 76–83.

Reineccius, G.A. (1989). Flavor encapsulation. *Food Rev. Int.*; 5: 147-176.

Rezende, Y.R.R.S.; Nogueira, J.P. and Narain, N. (2018). Microencapsulation of extracts of bioactive compounds obtained from acerola (Malpighia emarginata DC) pulp and residue by spray and freeze drying: Chemical, morphological and chemometric characterization. *Food Chem.*; 254: 281–291.

Rodriguez-Amaya, D.B. (2018). Update on natural food pigments—A mini-review on carotenoids, anthocyanins, and betalains. *Food Res. Int.*; 124: 200-205.

Saikia, S.; Mahnot, N.K. and Mahanta, C.L. (2015). Optimisation of phenolic extraction from Averrhoa carambola pomace by response surface methodology and its microencapsulation by spray and freeze drying. *Food Chem.*; 171: 144–152.

Santiago-Adame, R.; Medina-Torres, L.; Gallegos-Infante, J.A.; Calderas, F.; González-Laredo, R.F.; Rocha-Guzmán, N.E.; Ochoa-Martínez, L.A. and Bernad-Bernad, M.J. (2015). Spray drying-microencapsulation of cinnamon infusions (*Cinnamomum zeylanicum*) with maltodextrin. *LWT Food Sci. Technol.*; 64: 571–577.

Shaddel, R.; Hesari, J.; Azadmard-Damirchi, S.; Hamishehkar, H.; Fathi-Achachlouei, B. and Huang, Q. (2018). Double emulsion followed by complex coacervation as a promising method for protection of black raspberry anthocyanins. *Food Hydrocoll.*; 77: 803–816.

Sneha, N. (2016). Microencapsulation of jamun (*Syzygium cumini* Skeels) juice powder by spray drying. M.Sc. Thesis. K.R.C. College of Horticulture College of Arabhavi (University of Horticultural Sciences, Bagalkot). Theses (/handle/1/65876).