



Effect of Different Drying Techniques on Quality Attributes of Ready to Reconstitute (RTR) Coffee Mix

C.S. Baladhiya ^{a++}, Karishma Mahla ^{b#}, Arpita M. Rathva ^{b†*}
and Ashish Patel ^{b†}

^a Department of Agricultural Engineering, B A College of Agricultural, AAU, Anand, India.

^b Department of Dairy Engineering, SMC Dairy Science College, KU, Anand, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/jsrr/2024/v30i62101>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/118027>

Original Research Article

Received: 24/03/2024

Accepted: 28/05/2024

Published: 04/06/2024

ABSTRACT

Coffee is one of the most ubiquitous and culturally significant beverages worldwide, transcending borders and influencing societies in myriad ways. Ready-to-reconstitute (RTR) coffee, often referred to as instant coffee, occupies a unique and significant niche in the global coffee market. In the present study, A mixture of Arabica to Robusta coffee beans in the ratio of 70:30 was found most suitable for manufacture of ready to reconstitute coffee mix. The concentrated coffee decoction prepared using this mixture is to be blended with concentrated milk (30%TS) in the ratio of 1:5 and dried using vacuum tray dryer, tray dryer and freeze dryer. The coffee mix is vacuum-dried at 30 to 45 degrees Celsius with a vacuum of 600 to 650 mm of Hg, gives better quality of dried product.

⁺⁺ Associate Professor;

[#] M.Tech. Student;

[†] Assistant Professor;

^{*}Corresponding author: E-mail: arpitarathva@gmail.com, arpitarathva@kamdhenuuni.edu.in;

Cite as: Baladhiya, C.S., Karishma Mahla, Arpita M. Rathva, and Ashish Patel. 2024. "Effect of Different Drying Techniques on Quality Attributes of Ready to Reconstitute (RTR) Coffee Mix". *Journal of Scientific Research and Reports* 30 (6):838-46. <https://doi.org/10.9734/jsrr/2024/v30i62101>.

The optimized final product has better rheological and physico chemical characteristics. In present study found that ready to reconstitute coffee mix has solubility in hot water 26.4 seconds and 2.74 minutes in cold water at 16°C. The freeze-dried coffee mix powder exhibited reduced flowability 42.08 seconds compare to vacuum tray dried and tray-dried coffee mix powder that was 47.41 and 46.27 seconds respectively. Same as bulk density of freeze-dried powder (0.64 g/cm³) found lowest compare to vacuum tray dried (0.78 g/cm³) and tray dried (0.82 g/cm³) coffee mix powder.

Keywords: Coffee; vacuum tray drying; tray drying; freeze drying; drying characteristic.

1. INTRODUCTION

Coffee is one of the most popular beverages not only India but also in the world. It is a main dietary source of polyphenol and phenolic acid. Coffee is considered a functional food, primarily due to its high content of compounds that exert antioxidant and other beneficial biological properties. Coffee beans are produced from the plant *Coffea L.*, of which there are more than 70 species, mainly two of these species are commercially explored worldwide: *coffea arabica* (Arabica), considered as the noblest of all coffee plants and providing 75% of world's production; and *coffea canephora* (Robusta), considered to be more acidic but more resistant to plagues, and provides 25% of world's production [1].

Coffee serves as more than just a drink; it is a symbol of hospitality, a stimulant for intellectual discourse, and a cornerstone of social rituals. Offering unparalleled convenience and an extended shelf life, RTR coffee has evolved from its humble beginnings into a sophisticated product with a variety of offerings that cater to diverse consumer preferences. The characteristic flavour and richness of coffee aroma make it a unique beverage, with almost a thousand volatile compounds identified in roasted coffee [2]. Despite facing competition from freshly brewed and ready-to-drink (RTD) coffee segments, RTR coffee remains popular due to its practicality, affordability, and continuous improvements in quality and flavour. The origins of instant coffee date back to the early 20th century, with the first commercially successful process developed by Japanese-American chemist Satori Kato. Since then, the industry has seen significant advancements, from freeze-drying and spray-drying techniques to the development of micro ground coffee, which enhances flavor and aroma [3-5].

The coffee tree is the part of the botanical family Rubiaceae, genus *coffea*. There are more than 100 species of coffee, however two of these are commercially traded. The commercially available

coffee consists almost entirely of *coffea arabica* (Arabica) and *coffea canephora* (Robusta) [6]. Most of the people consume coffee due to its rich aroma, colour and delightful flavour [7,8-10]. The green coffee bean differs from each other in their chemical content. It has been reported that Arabica coffee contains more lipids than Robusta, while the Robusta contains more caffeine and polyphenols than Arabica [11]. Additionally, coffee beans contain vitamin of complex B, the niacin (vitamin B3 and PP), and chlorogenic acid in proportions that may vary from 7% to 12%, Belitz et al. 2009; Lima [12] Trugo [13] The caffeine content plays an important role in popularity of coffee [14]. The specification for soluble coffee (instant coffee) powder was first published in 1964 and subsequently revised in 1972 and 1983. Coffee is pleasure. Its taste, flavor, aroma, and refreshing effect make it unique. Most people consumed coffee due to its aroma, color and flavor [7]. It is also a product that attracts great attention in the food and beverage industry. Ready to reconstituted coffee mix contain milk solids, sugar and coffee powder in optimized condition with additional ingredients that increase the convince of use and increase the shelf life compare to ready to drink coffee. So, these technological advancements have helped RTR coffee shed some of its earlier reputational challenges, positioning it as a viable option for both everyday consumption and culinary applications [15-19].

So, ready to drink coffee has less shelf life compare to ready to reconstitute coffee mix. Also found that ready to drink coffee has disadvantages like as handling and transportation, packaging etc. so in this present study tried to overcome the limitations in ready to drink coffee by mixing of milk solids and coffee decoction at an optimum rate, and after mixing it was dried by using three different techniques to made acceptable product with better quality ready to reconstitute coffee mix powder. It can attract great attention in the food and beverage industry.

2. MATERIALS AND METHODS

2.1 Coffee Decoction

In present study, two variety of coffee beans selected that is Arabica and Robusta. In instant coffee production Arabica beans contain higher number of soluble solids and therefore increase yield. Robusta has more caffeine compared to Arabica. Also has low acidity and high bitterness. Arabica and Robusta procured from Madhya Pradesh. Ground-roast coffee generally consists of Arabica species alone or a high percentage of Arabica. Ingredients used for making ready to reconstitute coffee mix are milk, sugar, emulsifier, sodium bicarbonate, trisodium citrate were used. Coffee decoction was prepared by mixing coffee powder with water ratio (1:10) at 80°C and holding the mixture at 80°C/ 60 min. in a water bath. Coffee filter paper (Model CCD#4.100) was used for coffee extraction. Concentration of coffee decoction filtrate and milk was done using an open pan. The total soluble solid ratio of coffee concentration and concentrated milk was 1:5 (30%TS). The concentrated decoction and concentrated milk were blended at 30°C. In this step stabilizer & emulsifier were added and properly mixed and held for 1-2 min. Lecithin, Sodium Bicarbonate (NaHCO₃) and Tri Sodium citrate were added @ 1.5, 1.5 and 1.5 per cent, respectively of total concentrate mix weight and concentrated mix was kept for 3-4 h holding for making coffee decoction before drying. The mix of blend coffee decoction and milk concentrate was spread in the tray for drying. The three dryers used for drying were tray dryer, vacuum tray dryer and freeze dryer.

2.2 Equipment for Drying

Drying methods (freeze drying, vacuum tray drying and tray drying) were used for preparation for ready to reconstitute coffee mix. In freeze dryer use the freezing temperature in the range of -35 to - 45 °C and freezing time was freezing Time: 18 - 28 h. Up to 200–250 g of samples was used per tray in tray dryer. In freeze drying plate temperature was maintained 50 and 60 °C. Hair and Strang [20] found that the drying time for freeze-drying of aqueous coffee extracts are reduced by allowing the temperature of the dried portion of the coffee extract to rise to from about 120 °F to about 200 °F. As long as shown the critical time-temperature relationships on the accompanying graph are maintained, no significant flavour loss is encountered. In vacuum

tray dryer temperature of steam used was 70 to 75°C. Temperature of drying chamber found 30 to 45 °C, when vacuum was adjusted to 600-650 (mm of Hg). In these condition with vacuum tray dryer we used sample quantity up to 500 to 600g of coffee decoction per tray. In tray dryer temperature of drying chamber was 70 °C with the sample quantity 500 g per of coffee decoction.

2.3 Physico Chemical Analysis

Acidity (0.1 N alkali/g sample) was determined as per the AOAC (1995). Moisture content was determined as per procedure by FSSAI [21]. Total ash content was determined as per procedure by FSSAI [21]. The pH was determined by a properly calibrated pH meter with a glass electrode. Fat content was determined as per procedure given by FSSAI [22]. Total solids content was determined as per procedure given by FSSAI [22].

2.4 Microbial Analysis

The ready to reconstitute coffee mix samples were analysed for the Standard Plate Count (SPC), Coliform count and (YMC) by the methods described in ISO 17792 (2006). Results are expressed as means of replications.

2.5 Rheological Analysis

Flowability was estimated using the method of Pisecky (1978). Solubility in boiling water was determined as per procedure given by FSSAI [22]. Particle size distribution was estimated using a sieve shaker. The sieves with 52µm, 100µm, 150µm and 200µm were used. Solubility in cold water was determined as per procedure given by FSSAI [22]. Bulk density was determined as per procedure given in BIS (2012). Flowability(s), Bulk density (g/cm³), Particle Size Distribution(µm), Solubility in hot water (s), Solubility in cold water at 16°C (min.).

2.6 Rate of Evaporation

Rate of evaporation (kg/h) represents the dryer capacity. It actually depicts the mass of moisture evaporated in the unit time.

2.7 Energy Consumption

The heat input to the dryer per unit mass of water evaporated. Drying unit energy consumption

included the refrigeration system, vacuum system and electric heater for maintaining the temperature during drying. For convective dryers the heat input is given as the power supplied to the heater and vacuum pump. Schuck et al. [23] according to their drying and vacuum concentration are valuable techniques for the removal of water, that study shows according to the type of product (biochemical composition, the ratio of bound and free water) and process (demineralization, vacuum evaporation, lactose crystallization, roller and spray, tray drying), the energy consumption for the production of powders were calculated. In tray dryer and freeze dryer energy meter was used to measure the energy consumption. In vacuum tray dryer steam used to maintain the temperature in the dryer so electrical cost and steam cost was also consider.

2.8 Statistical Analysis

The data regarding engineering aspects noted during trials were used to study selected drying techniques for production of ready to reconstitute coffee mix. Mean value generated during sensory evaluation by applying a combination of treatments were subjected to Statistical analysis using Factorial Completely Randomized Design (FCRD) as per Steel and Torrie [24].

3. RESULTS AND DISCUSSION

3.1 Drying Behavior

Rate of evaporation (kg/h) represents the capacity of the dryer. It actually depicts the mass of moisture evaporated in the unit time. This was calculated from the difference of moisture in coffee milk mix powder obtained during the trial. Three different drying methods viz. tray drying, vacuum tray drying and freeze drying were used.

Effect of tray drying at constant temperature of 70°C on the weight of coffee mix is graphically represented in Fig. 1. It represented the weight loss (kg/h) in approximately 8 h. It can be seen that the weight loss followed an exponential trend as commonly seen in the drying of food products. Effect of rate of evaporation in vacuum tray drying on drying time (h) was represented it took 8 to 12 h to prepared reconstitute coffee mix. Fig. 2 showed that the rate of evaporation (kg/h) was decrease in increase with drying time. The rate of evaporation was 0.32, 0.19 and 0.17 kg/h of moisture removed in 8.5 h, 10.5 h and 12.0 h, respectively. Effect of freeze-drying temperature

on drying time of coffee milk mix is represented graphically. In most cases, the food is frozen before being loaded into the dryer [25]. Fig. 3 showed that freeze drying hot plate temperature at 50 and 60 °C take a 18 h to 15 h drying time for evaporation of moisture. Freeze drying process was taking a more time compare to tray drying and vacuum tray drying method. The thickness of food is shaped to present the largest possible flat surface to the expanded metal and the plates to obtain good heat transfer. A refrigerated condenser may be used to condense the water vapor [26]. From the above figure can say that time drying time is maximum in freeze dryer and then followed by vacuum tray dryer and tray dryer. So, there is significant difference in rate of evaporation in selected drying techniques. Drying temperatures should be carefully controlled, during the major part of the drying cycle. Drying times are typically long (usually 12 to 48 h) [27]. Optimization of the process for the manufacture of RTR Carrot Halwa mix using vacuum tray drying method. In RTR Carrot Halwa mix, drying of carrot halwa at 670-690 mmHg vacuum at 37-43°C for 5 h [28].

3.2 Energy Analysis

Energy analysis for tray drying, vacuum tray drying and freeze drying of ready to reconstitute coffee mix was carried out. In freeze drying a single-phase energy meter was attached to the freeze dryer machine to determine the electricity consumed during freeze drying process. In this freeze dryer there was separate freezer for freezing unit. Total energy consumption is summation of the energy consumptions of freezing unit and drying unit. In tray drying a three-phase electrical heater was used in tray drying process and the energy consumption by electrical heater during drying of product was noted. In vacuum tray drying process the energy consumption was calculated during processing of drying include the vacuum pump operated by electrical energy and thermal energy used as steam. In present study results found that in freeze drying, tray drying and vacuum tray drying energy consumption (kWh/kg of coffee mix) is 13.12, 9.45 and 11.32 respectively. Chaudhary [29] the studied on the performance evaluation of freeze dryer for manufacture of freeze-dried fruits and its application in manufacture of fruit chocolate confection. During freeze drying process he observed that the total energy consumption of guava, pineapple and strawberry pulp was 13.00, 14.37 and 15.10 kWh, respectively.

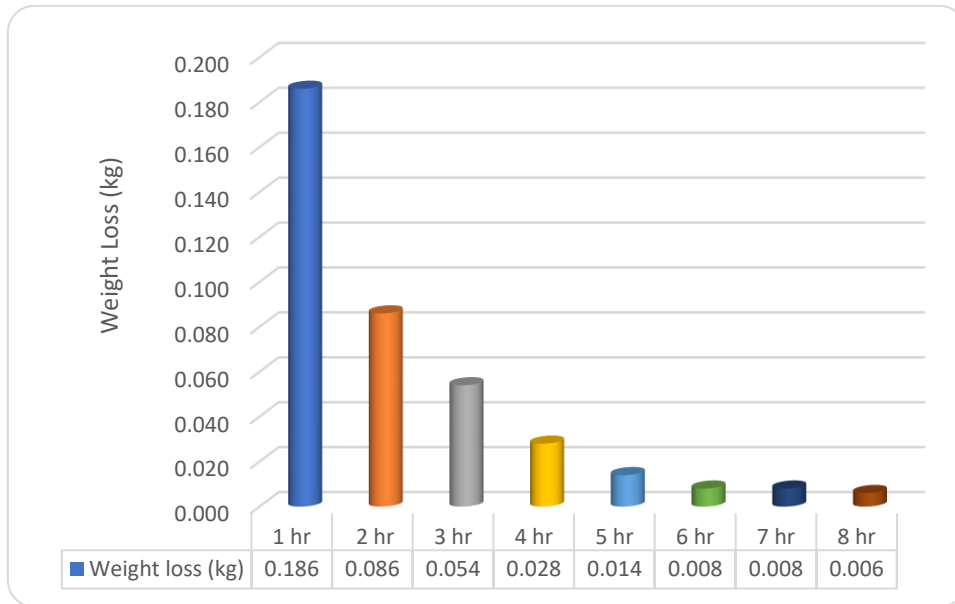


Fig. 1. Effect of rate of evaporation in tray drying method

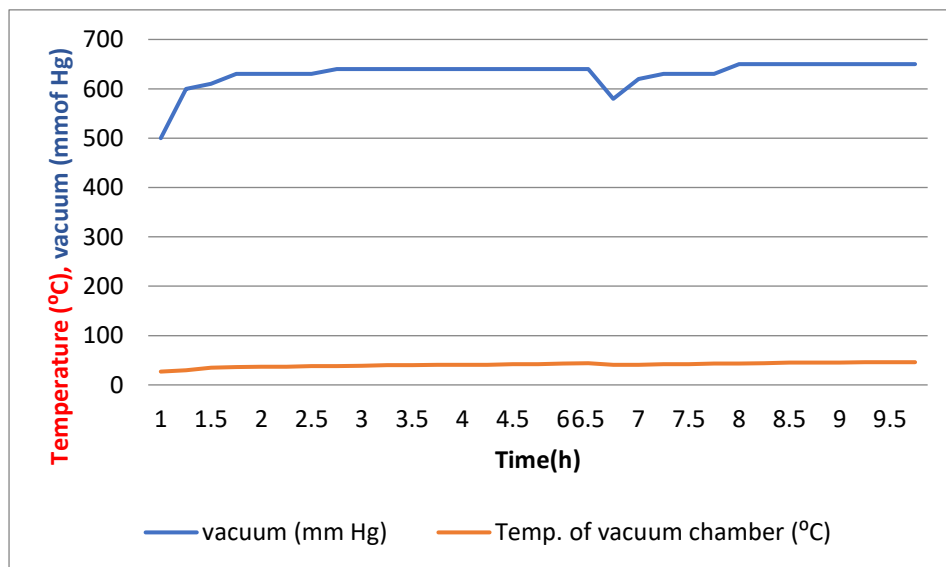


Fig. 2. Vacuum and temperature maintained during in vacuum tray drying

3.3 Comparison of Chemical, Microbial and Rheological Analysis of Optimized Product

The optimized ready to reconstitute coffee mix prepared by using tray drying, vacuum tray drying and freeze tray drying was analysed for its chemical composition, microbial quality, rheological properties. Chemical analysis of coffee decoction viz. acidity (0.1 N alkali consumed/g sample), moisture (%), TS (%brix), total ash (%) and pH were 3.92, 69.49, 30, 5.24 and 5.83, respectively. The concentrated milk,

which was used for preparation of ready to reconstitute coffee mix was analysed for its acidity, fat and TS content. Present study showed the results of chemical analysis of concentrated milk. The acidity (% LA), fat (%) and TS (%) were 0.69, 10.44 and 30, respectively.

3.4 Physicochemical Analysis

The moisture, total ash and acidity of ready to reconstitute coffee mix sample is presented in Table 1. The sample met the FSSAI [30]

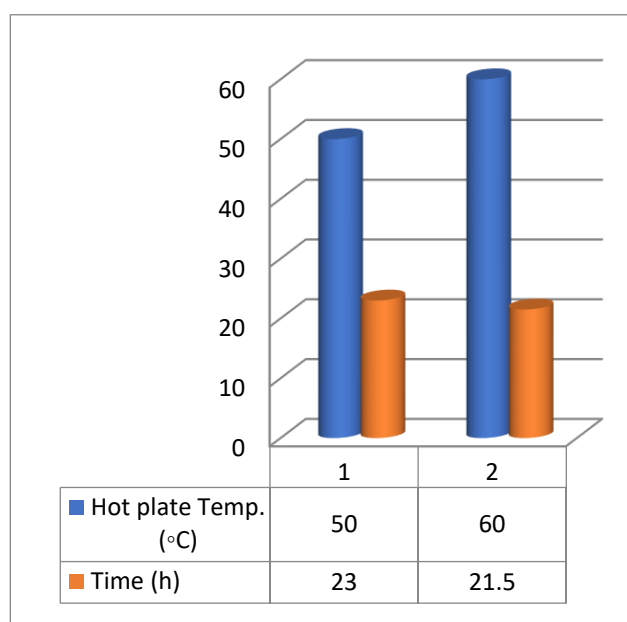


Fig. 3. Time temperature used for drying in freeze dryer

Table 1. Comparative appraisal of coffee powder mix prepared by different drying methods

Parameters	Tray Drying	Vacuum Tray drying	Freeze drying
Moisture (%)	3.58±0.69	3.85±0.59	3.90±0.42
Total Ash (%)	6.21±0.13	6.90±0.13	6.88±0.22
Acidity (0.1 N alkali/g sample)	1.3±0.08	1.21±0.08	1.3±0.07
SPC (cfu/g)	98.2±2.16	102±5.70	103±8.76
Coliform (cfu/g)	Nil	Nil	Nil
Yeast & Mold(cfu/g)	Nil	Nil	Nil
Flowability(s)	46.27±1.56	47.41±2.91	42.08±2.87
Bulk density (g/cm ³)	0.82±0.01	0.78±0.06	0.64±0.06
Particle Size Distribution(μm)	180±27.39	170±27.39	176±27.39
Solubility in hot water (s)	26.8±1.14	26.4±1.64	25.2±1.09
Solubility in cold water at 16°C (min.)	2.78±0.15	2.74±0.15	2.72±0.08

requirements with respect to moisture and total ash. The moisture (%), total ash (%) and acidity (0.1 N alkali consumed/g sample) of the ready to reconstitute coffee mix was 3.90, 6.88 and 1.3, respectively for freeze drying. 3.85, 6.90 and 1.21, respectively for vacuum tray dried ready to reconstitute coffee mix and 3.58, 6.21 and 1.3, respectively for tray dried ready to reconstitute coffee mix. Freeze-drying is known to result in the highest quality of foods amongst all drying techniques because structural integrity is maintained along with the preservation of flavours. It is used mainly with high-value products [31]. The present study results of the analysis are summarized as vacuum tray dried sample have a comparatively lower total ash content compare to other two drying mechanism also shows that non-significant difference in

Other two parameters like acidity and moisture content.

3.5 Microbial Analysis

Drying is the oldest technique of preservation where the moisture is brought down to a level at which microbial growth is not supported [32]. The ready to reconstitute coffee mix samples were analyzed for its SPC, coliform and yeast and mold count. Table 1 shows the results of SPC (cfu/g), coliform (cfu/g) and yeast & mold counts (cfu/g) of the sample. These values met the ISO 17792 (2006) requirements with respect to SPC, coliform and yeast and mold count. SPC (cfu/g) of the ready to reconstitute coffee mix was 103 cfu/g, 102 cfu/g and 98.2 cfu/g in freeze dried, vacuum tray dried and tray dried ready to

reconstitute coffee mix respectively. Other microbial analysis like coliform and yeast and mold were not detected in all three drying methods used. The present data shows that the powder have a higher shelf life with good microbial quality. The primary purpose of freeze-drying within the food industry is to extend the shelf-life of the food while maintaining quality because freeze drying is a vacuum process and absence of oxygen prevents oxidative deterioration [33].

3.6 Rheological Analysis

The ready to reconstitute coffee mix sample was analysed for its flowability, bulk density, particle size distribution and solubility in hot and cold water. Table 1 shows the results of rheological analysis of the freeze dried ready to reconstitute coffee mix. It can be observed from the table that the flowability (sec), bulk density (g/cm^3), particle size distribution (μm), solubility in hot water (sec) and solubility in cold water at 16°C (min.) were found to be 46.27, 0.82, 180, 26.8 and 2.78, 47.41, 0.78, 170, 26.4 and 2.74, 42.08, 0.64, 176, 25.2 and 2.72 for tray dried, vacuum tray dried and freeze dried ready to reconstitute coffee mix respectively. The present data shows that solubility in hot water (s) and Solubility in cold water at 16°C (min.) is much higher in freeze dried coffee mix powder compare to other two drying methods. Particle Size Distribution (μm) is much lesser in vacuum tray drying method followed by freeze drying and tray drying method. Gebeyehu and Bikila [34] reported that Freeze drying dried coffee has spherical shape with the size of about $40\mu\text{m}$ and flaky structure. The free bulk density of $0.338\text{ g}/\text{cm}^3$ freeze dried coffee. They reported the higher values of freeze-dried powder bulk density can be due to its higher residual moisture content, and wider particle size distribution.

4. CONCLUSION

The present study reveals that, the freeze dried of ready to reconstitute coffee mix powder found better compared to the vacuum and tray drying of ready to reconstitute coffee mix in optimized conditions. In energy cost used for drying is comparatively higher in freeze drying than vacuum tray drying. Rate of evaporation is higher in vacuum tray dryer than freeze dryer. Based on the results obtained in this study it can be concluded that a mixture of Arabica to Robusta coffee beans in the ratio of 70:30 is most suitable. The concentrated coffee decoction

prepared using this mixture is to be blended with concentrated milk (30% TS) in the ratio of 1:5 and dried using vacuum tray dryer to obtain an acceptable quality ready to reconstitute coffee mix. In vacuum tray dried RTR mix showed solubility in hot water 26.4 seconds and 2.74 minutes in cold water at 16°C . In terms of bulk density and flowability are much better in vacuum tray dryer and freeze dryer compare to tray dryer. So, in view of all the above and in consideration of cost and energy utilization vacuum tray drying method for drying of RTR coffee mix has beneficial effect.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chergaoui S, El Hajjaji S, Lghoul R. Large-Scale Coffee Oil Extraction; 2017.
2. Yeretizian C, Jordan A, Lindinger W. Analysing the headspace of coffee by proton-transfer-reaction mass-spectrometry. *International Journal of Mass Spectrometry*. 2003;223:115-13.
3. Dehnad D, Jafari SM, Afrasiabi M. Influence of drying on functional properties of food biopolymers: From traditional to novel dehydration techniques. *Trends in Food Science & Technology*. 2016;57:116-131.
4. Gaidhani KA, Harwalkar M, Bhambere D, Nirgude PS. Lyophilization/freeze drying—a review. *World journal of pharmaceutical research*. 2015;4(8):516-543.
5. Inyang U, Oboh I, Etuk B. Drying and the different techniques. *International Journal of Food Nutrition and Safety*. 2017;8(1):45-72
6. Dias R, Benassi M. Discrimination between arabica and robusta coffees using hydrosoluble compounds: is the efficiency of the parameters dependent on the roast degree beverages. 2015;1(3): 127-139.
7. Van Doorn GH, Willemin D, Spence C. Does the colour of the mug influence the taste of the coffee?. *Flavour*, 2014;3(1):10.
8. Khairnar S, Kini R, Harwalkar M. *International Journal of Research in Pharmacy and Science*. Int. J. Res. Pharm. Sci., 2013;76.

9. Krokida MK, Maroulis ZB. Effect of drying method on shrinkage and porosity. *Drying technology*. 1997;15(10): 2441-2458.
10. Rajeevini K, Mahalakshmi K, Uma MRV. Review on Lyophilization technique, *International Journal of trends in pharmacy and life sciences*. 2015;1(1):130–140.
11. Cagliani LR, Pellegrino G, Giugno G, Consonni R. Quantification of *Coffea arabica* and *Coffea canephora* var. *robusta* in roasted and ground coffee blends. *Talanta*, 2013;106:169-173.
12. Lima DR. *Café e Saúde: Manual de Farmacologia Clínica, Terapeutica e Toxicologia*. Rio de Janeiro: Medsi Editora; 2003.
13. Trugo L. Coffee. In B. Caballero, L. Trugo, & P. Finglas (Eds.), *Encyclopedia of Food Sciences and Nutrition* (2nd ed.). London: Academic; 2003.
14. Topik S. Coffee as a social drug. *Cultural Critique*. 2009;71(1):81-106.
15. Solchansanj S, Jayas DS. Drying of foodstuffs. In *Handbook of industrial drying*. 2020:589-625.
16. Varelziz P, Gargali I, Kiroglou S, Zeleskidou M. Production of instant coffee from cold brewed coffee; process characteristics and optimization. *Food Science and Applied Biotechnology*. 2020; 3(1):39-46.
17. Utama AH, Sari Y, Andiana P, Kasri, Faradila R, Awwaly KUA, Radiati LE. Total Microbiological and Chemical Quality of Dry Fermented Mare's Milk Sumbawa Using Gum Arabic (*Acacia senegal*) as Encapsulating Agent. *AFSJ*. 2024;23(3): 20-7.
Available:<https://journalafsj.com/index.php/AFSJ/article/view/703>
[Accessed on: 2024 May 23]
18. Gomaa MA. Evaluation of Natural Pigments Extracted from Tomato Wastes and the Possibility of their Encapsulation. *Eur. J. Nutr. Food. Saf.* 2022;14(9):69-78.
Available:<https://journalejnfs.com/index.php/EJNFS/article/view/719>
[Accessed on: 2024 May 23]
19. Roy I, Gupta MN. Freeze-drying of proteins: Some emerging concerns. *Biotechnology and applied biochemistry*. 2004;39(2):165-77.
20. Hair ER, Strang DA. Method of freeze-drying coffee extracts. *US*. 1969;3: 486,907.
21. FSSAI. Lab manuals of methods of analysis of beverages (coffee, tea, cocoa, chicory) sugar and sugar products & confectionery products. Food safety and standards authority of India ministry of health and family welfare government of India, New Delhi; 2014.
22. FSSAI. Lab manuals of methods of analysis of food milk and milk products. Food safety and standards authority of India ministry of health and family welfare government of India, New Delhi; 2012.
23. Schuck P, Jeantet R, Bhandari B, Chen XD, Perrone ÍT, de Carvalho AF, Kelly P. Recent advances in spray drying relevant to the dairy industry: A comprehensive critical review. *Drying Technology*. 2016;34 (15):1773-1790.
24. Steel RGD, Torrie JH. *Principles and procedures of statistics- a Biometrical approach*. (2nd ed.), Japan.: Mc Graw Hill Kogakusha Ltd; 1980.
25. Vega-Mercado H, Góngora-Nieto MM, Barbosa-Cánovas GV. Advances in dehydration of foods. *Journal of Food Engineering*. 2001;49(4):271- 289.
26. Kakac S, Liu H, Pramuanjaroenkij A. *Heat Exchangers: Selection, Rating, and Thermal Design*. 2020;143-159.
27. Parikh DM. *Solids drying: Basics and applications*. *Chemical Engineering*. 2014; 121(4):42-45.
28. Modha HM., Vaghela NR, Gokhale AJ, Patel AM, Patel HG. Process standardization for manufacture of Ready-to-Reconstitute Carrot Halwa mix. *Indian Journal of Dairy Science*. 2016;69(4).
29. Chaudhary HK. Performance evaluation of freeze dryer for manufacture of freeze dried fruits and its application in manufacture of fruit chocolate confection (Doctoral dissertation, Department of Dairy Engineering Sheth MC College of Dairy Science Anand Agricultural University, Anand); 2017 .
30. FSSAI. Food Safety Standards act; 2011. Available:www.fssai.gov.in
31. Raman P. Freeze drying microscopy as a tool to study sublimation kinetics (Doctoral dissertation, Loughborough University, UK); 2015.
32. Ciużyńska A, Lenart A. Freeze-drying-application in food processing and biotechnology-a review. *Polish Journal of Food and Nutrition Sciences*. 2011;61(3): 165-171.

33. Bonazzi, C. and Dumoulin, E. Quality changes in food materials as influenced by drying processes. *Modern Drying Technology*. 2011; 3:1-20
34. Gebeyehu BT, Bikila SL. Determination of caffeine content and antioxidant activity of coffee. *American Journal of Applied Chemistry*. 2015;3(2):69-76.

© Copyright (2024): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:

<https://www.sdiarticle5.com/review-history/118027>