Short Research Article

Significance of different drying techniques on quality attributes of Ready to reconstitute coffee mix.

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. In vacuum tray drying at 30 to 45^{o}C under vacuum of 600 to 650 mm of Hg to obtain an acceptable quality ready to reconstitute coffee mix. 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 (s) 26.4 seconds and 2.74 minutes in cold water at 16˚C.

Key words: Coffee, Vacuum tray dying, Tray drying, Freeze drying, Drying characteristic

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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:coffeaarabica (Arabica), considered as the noblest of all coffee plants and providing 75% of world's production; and coffeacanephora (Robusta), considered to be more acidic but more resistant to plagues, and provides 25% of world's production (Chergaoui et al.,2017).

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 (Yeretzian*et al.,* 2003). 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.

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 coffeaarabica (Arabica) and coffeacanephora (Robusta) (Dias and Benassi, 2015). Most of the people consume coffee due to its rich aroma, colour and delightful flavour (Van Doorn et al., 2014). 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 (Caglian*iet al.,* 2013). 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 2003; Trugo 2003. The caffeine content plays an important role in popularity of coffee (Topik, 2009). 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 (Van Doorn et al., 2014). 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.

Comment [S44]: Introduction part can be concluded with the short come of previous literature to define the gap and how author planned to execute the work followed by the analysis that are carried out.

2.MATERIAL 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 ($NaHCO_3$) 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 ℃ and freezing time was freezing Time: 18 - 28 h. In the present study we were used sample quantity up to 200 - 250 g per tray. In freeze drying plate temperature used was 50 and 60 ℃. Hair and Strang (1969) found that the drying time for freeze-drying of aqueous coffee extracts are reduced by allowing the temperature of the dried portion of thecoffee extract to rise to from about 120 °F to about 200 °F. As long as shown thecritical time-temperature relationships on the accompanying graph are maintained, nosignificant flavour loss is encountered. In vacuum tray dryer temperature of steam used was 70 to75℃. Temperature of drying chamber found 30 to 45 ℃, 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 ℃ 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 (2015). Total ash content was determined as per procedure by FSSAI (2015). The pH was determined by a properly calibrated pH meter with a glass electrode. Fat content was determined as per procedure given by FSSAI (2012). Total solids content was determined as per procedure given by FSSAI (2012).

2.4 Microbial analysis:

The ready to reconstitute coffee mix samples were analysed for the StandardPlate Count (SPC), Coliform count and (YMC) by the methods described in ISO17792 (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 (2012). 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 (2012). Bulk density was determined as per procedure given in BIS (2012). Flowability(s), Bulk density (g/cm^3), 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. This was calculated from the difference of moisture in coffee milk mix and powder obtained during the trial.

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,* (2016) according to their drying and vacuum concentration arevaluable

Comment [S45]: Rewrite the sentence.

Comment [S46]: Used or maintained?

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Comment [S48]: What is the heat source in tray dryer?
What is the air flow rate maintained during drying?

Comment [S49]: Author could check the correctness of the statement for finding rate of evaporation. Kindly give expressions for finding the parameters in all the respective places

techniques for the removal of water, that study shows according to the type ofproduct (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.

2.8 Statistical analysis:

The data regarding engineering aspects noted during trials were used to studyselected drying techniques for production of ready to reconstitute coffee mix. Meanvalue generated during sensory evaluation by applying a combination of treatmentswere subjected to Statisticalanalysis using Factorial Completely Randomized Design(FCRD) as per Steel and Torrie (1980).

3.RESULTS AND DISCUSSION:

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^{o}C on the weight of coffee mix is graphically represented in Figure 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. Figure 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 0.17kg/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 (Vega- Mercado *et al.,* 2001). Figure 3 showed that freeze drying hot plate temperature at 50and 60^{o}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 try 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 (Kakac *et al.,* 2020). 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 can be carefully controlled, during the major part of the drying cycle. Drying times are typically long (usually 12 to 48 h) (Parikh, 2014).

Comment [S410]: Kindly mention the expression to find the energy consumption

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Comment [S412]: What is the initial moisture content?
How much quantity of water to be removed?
Authors can provide the above details in section 3

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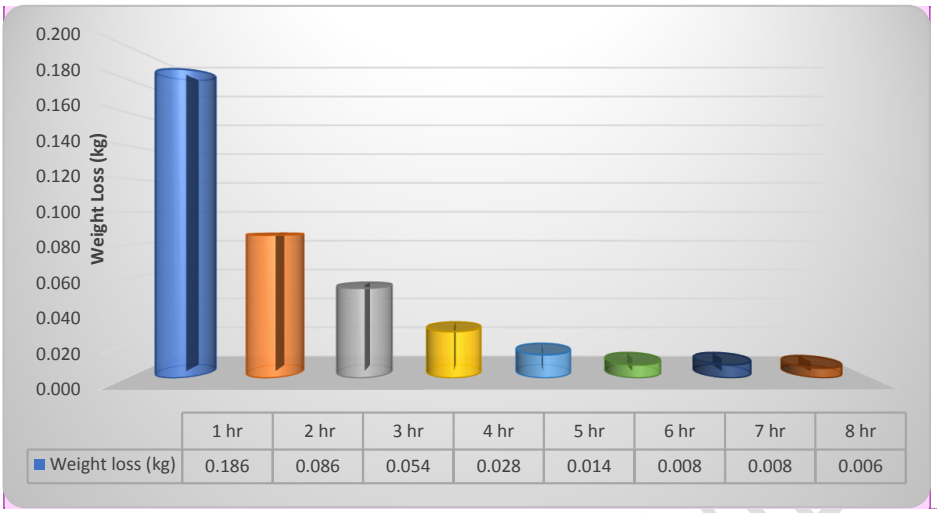

	1 hr	2 hr	3 hr	4 hr	5 hr	6 hr	7 hr	8 hr
Weight loss (kg)	0.186	0.086	0.054	0.028	0.014	0.008	0.008	0.006

Figure 1: Effect of rate of evaporation in tray drying method

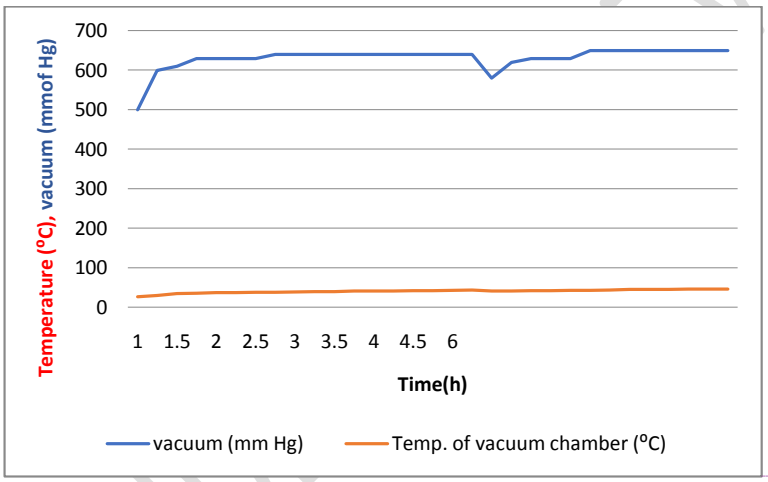

Figure2: Vacuum and temerature maintain in vaccum tray dryer

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The caption is appropriate

Comment [S416]: What about the variation of temperature in other processes. Author can include the variation of temperature in other processes also.

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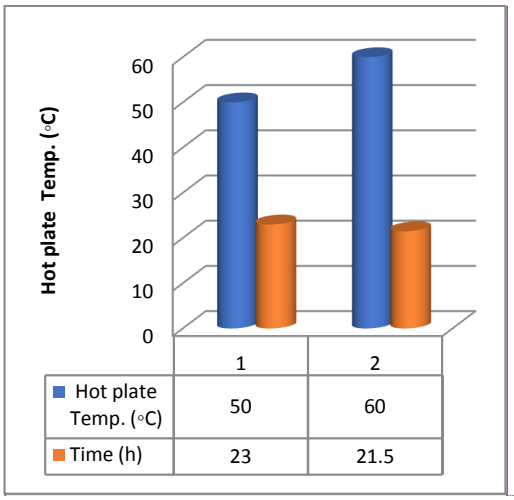

Figure 3: Time temerature used for drying in freeze dryer

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 (2017) the studied on the performance evaluation of freeze dryerfor manufacture of freeze-dried fruits and its application in manufacture of fruitchocolate confection. During freeze drying process he observed that the total energyconsumption of guava, pineapple and strawberry pulp was 13.00, 14.37 and 15.10kWh, respectively.

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

The optimized ready to reconstitute coffee mixprepared 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 (^{o}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 mixwas analysed for its acidity, fat and TS content. Present study

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showed the results of chemical analysis of concentrated milk. The acidity (% LA), fat (%) and TS (%) were 0.69, 10.44 and 30, respectively.

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 (2011) 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 (Raman, 2015). 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.

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 (Ciurzyńska and Lenart, 2011). 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 mixwas 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 andmold 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 (Bonazzi and Dumoulin, 2011).

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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 1shows 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 ^{o}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 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 (2015) reported that Freeze drying dried coffee has spherical shape with the size of about 40µm and flaky structure. The free bulk density of 0.338 g/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.

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 SizeDistribution(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

Conclusion:

The freeze drying of ready to reconstitute coffee mix is possible and gives acceptable results 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 1:5and dried using vacuum tray dryer to obtain an acceptable quality ready to reconstitute coffee mix. Overall rheological characteristics 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 ready to reconstitute coffee mix has beneficial effect.

Comment [S423]: Present more technical outcome of the work. Try to cover all the analysis.

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