Journal of Food Technology Research
2026 Vol. 13, No. 4, pp. 1-12
ISSN(e): 2312-3796
ISSN(p): 2312-6426
DOI: 10.18488/jftr.v13i4.5188

Optimization of the inlet temperature during spray drying increases the productivity and quality of kefir powder

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Article History
Received: 29 September 2025
Revised: 4 June 2026
Accepted: 13 July 2026
Published: 16 September 2026

Keywords
Inlet and outlet temperatures
Kefir powder
Microbial viability
Physicochemical properties
Productivity
Spray drying.

ABSTRACT

This study aimed to optimize the inlet temperature for the spray drying process to increase productivity, improve physicochemical quality, and maintain the viability of microorganisms in the kefir products. Kefir was powdered using a laboratory-scale spray dryer at inlet temperatures of 120 °C, 140 °C, 160 °C, and 180 °C, coupled with a feed pump rate to maintain the desired outlet temperature between 66 and 68 °C. The outlet temperature was obtained by increasing the pump rate at higher inlet temperatures and controlling atomization pressure and aspirator pressure. The physicochemical quality and microbial viability at different inlet temperatures and processing times, and the yield of dried kefir were observed. The results revealed that an inlet temperature of 160 °C showed the most effective drying condition. This inlet temperature recorded a faster process rate (19.35 ml/min) with decreased residence time (20.67±0.94 min) while maintaining high bacterial viability (8.75 log CFU/g) and protein content (15.14±0.28%) in the products. The inlet temperature of 160 °C has an impact on high productivity, while the outlet temperature of 66 – 68 ℃ maintains physicochemical quality and microbial viability. These spray-drying parameters can be applied in commercial kefir production to produce marketable products with better manufacturing efficiency.

Contribution/Originality: This study is one of the few studies that investigates the spray drying process of kefir by setting a similar outlet temperature to a range of inlet temperature that contributes to process productivity, while maintaining good physicochemical properties and microbial viability.

1. INTRODUCTION

Kefir is a fermented milk product using kefir grains as inoculum, which consists of lactic acid bacteria (LAB), yeast, and acetic acid bacteria (Kesenkaş, Gürsoy, & Özbaş, 2017). Kefir is susceptible to the growth of spoilage and pathogenic microorganisms due to its nutritional and water content, which leads to a limited shelf life (Tontul, Ergin, Eroğlu, Küçükçetin, & Topuz, 2021). Common storage of kefir product usually involves refrigeration in liquid form. However, long-term cold storage in its liquid form causes physicochemical, biochemical, and microbiological deterioration. This condition challenges more practical storage and packaging alternatives. High water activity in liquid kefir keeps spoilage microorganisms active, thus limiting its shelf life. An effective solution to this challenge is to remove the water content by turning it into powder. Kefir powder provides additional advantages, including improved compact storage, distribution efficiency, and extended shelf life (De Oliveira et al., 2021).

The drying methods that are commonly used to produce dried products include spray, roller, pan, and freeze drying. Among these drying methods, spray drying is particularly suitable for drying liquid foods with low soluble solids, including kefir. Spray drying is a fast, cheap, and efficient method for converting liquid food into powder (Schuck, Jeantet, & Dolivet, 2012; Seville, Learoyd, Li, Williamson, & Birchall, 2007; Timilsena, Haque, & Adhikari, 2020), but high temperatures and rapid drying processes can negatively affect microbial viability (Anandharamakrishnan & Ishwarya, 2015).

According to previous studies, spray drying involves various parameters that can be optimized (Bellinghausen, 2019). Although several studies examining spray drying have focused on the inlet temperature, few have considered the outlet temperature as an important parameter. Therefore, information on the effects of outlet temperature variations on the productivity and quality of powder is limited. Spray drying within an outlet temperature range of 60–80 °C has been reported to have little effect on the quality of milk products (Habtegebriel, Wawire, & Sila, 2018; Zamora & Hidalgo, 2005). Whereas inlet temperature is the most affecting factor for productivity and quality (Atalar & Dervisoglu, 2015). High productivity is characterized by high yields, indicating efficient processing and economic feasibility (Moghbeli, Jafari, Maghsoudlou, & Dehnad, 2019). To achieve the high productivity and quality of the powder, optimization of spray drying inlet temperature combined with low outlet temperature needs to be investigated.

In this study, the optimization of various inlet temperatures between 120 and 180 °C and the outlet temperature between 66 and 68 °C was evaluated on the basis of productivity, physicochemical quality, and microbial viability. High inlet temperature of 180 °C has been reported to preserve nutritional content (Yaakub, Zaini, & Xiang, 2019), and the lowest inlet temperature at 120 °C was chosen to accommodate the limitations of the spray dryer pump capacity. This study tries to investigate whether variation of inlet temperatures of 120, 140, 160, and 180 °C that are combined with outlet temperature between 66 and 68 °C can improve productivity and quality of kefir powder. The optimized combination of inlet and outlet temperature can therefore be applied in commercial kefir powder production with cost-effective processing.

2. LITERATURE REVIEW

Several drying methods are commonly used for food, including pan drying, spray drying, and freeze-drying. Compared with spray drying, freeze-drying results in superior sensory characteristics and microbial viability, but this process is too expensive for industrial applications (Atalar & Dervisoglu, 2015).

Spray drying is a drying method that produces a powdered product. Like other drying methods, this method reduces the water content of the material. In general, the main goal of drying is to remove water and reduce the storage space. This saves transportation costs and facilitates distribution (Tontul et al., 2021). Spray drying results in lower specific energy consumption than freeze-drying does, resulting in higher productivity (Huang et al., 2017). Spray drying is the most economically feasible method to produce powdered products, including those with heat-sensitive components. One product suitable for spray drying is LAB-containing milk powder (Barbosa, Brandão, & Teixeira, 2017), which can be made from kefir. Many studies have been conducted using spray drying methods, but few have addressed the outlet temperature. The appropriate outlet temperature is vital for maintaining microbial viability in the powder (Chen & Patel, 2007). The outlet temperature cannot be controlled directly but depends on the inlet temperature and the conditioned pump rate (Young, Sarda, & Rosenberg, 1993). Felfoul et al. (2022) reported that the outlet temperature approach is an effective way to increase productivity and to preserve nutritional quality (Felfoul et al., 2022).

3. MATERIAL AND METHODS

3.1. Kefir Production

Kefir was produced from milk pasteurized using the high-temperature short-time (HTST) technique at 73 °C for 15 seconds. The pasteurized milk was weighed to determine the addition of kefir grains at a concentration of 5% (w/v). Subsequently, the inoculated milk was incubated at room temperature for 24 hours, and the kefir products were harvested and filtered.

3.2. Drying Processes

Liquid kefir was spray dried using a laboratory-scale Buchi B-290 spray dryer (Mini Spray Dryer Be290, Switzerland) (Movahhed & Mohebbi, 2016) with some modifications. The varying inlet temperatures of 120 °C (T1), 140 °C (T2), 160 °C (T3), and 180 °C (T4) were applied in the spray drying process as parameters to produce kefir powder. The drying process utilized an atomization air flow rate setting of 60 mL/second, a 100% vacuum aspirator, a nozzle cleaner set to 2, and a pump adjusted to the inlet temperature to achieve an outlet temperature of 66–68 °C, and the process was repeated three times. Several measurable parameters could be configured on the basis of these settings. Table 1 presents the process parameters that were set on the equipment as well as the parameters that were recorded.

Table 1. Settings and parameters of the spray dryer equipment.

No.	Treatment	Inlet Temp (°C)	Atomization Pressure (mbar)	Aspiration Pressure (%)	Outlet Temp (°C)	Vacuum (mBar)	Feed Pump (%)
1	T1	120	600	100	66-68	-55	30
2	T2	140	600	100	66-68	-55	45
3	T3	160	600	100	66-68	-55	65
4	T4	180	600	100	66-68	-55	80

The process time was obtained by calculating the time to use up 400 ml of liquid kefir; the process rate was calculated based on Equation 1.

$$Q = \frac{\Delta v}{\Delta t} \quad (1)$$

Where Q = Process rate (ml/min); Δv = Material volume (ml); and Δt = Process duration (minutes).

3.3. Yield and Quality of Kefir Powder

These analyses were carried out to obtain the percentage of solid weight obtained from the weight of the liquid material at a certain volume. The yield was estimated according to the official method of analysis of the AOAC (2005). Liquid kefir was poured into a beaker, and its mass was recorded as the initial weight. Additionally, the liquid kefir was spray dried, and the final weight of the collected powder was recorded. The yield was calculated using Equation 2.

$$\text{yield} = \frac{\text{final weight}}{\text{initial weight}} \times 100\% \quad (2)$$

Wettability testing was performed using the AOAC (2005) method. Ten grams of milk powder and 68.18 mL of distilled water were added to a 250 mL beaker at 40 °C. The milk powder sample was then poured onto the surface of the water. The wettability time was recorded on the basis of the total time (seconds) required for the powder to fully dissolve in the water. The morphology of the kefir powder particles was observed using scanning electron microscopy (SEM) using a Hitachi type SU-3500 microscope (Tescan, Brno, Czech Republic) at a voltage of 3 kV, with magnification levels ranging from 1000× to 5000×. The SEM images were evaluated in triplicate via ImageJ to determine the particle size of kefir powder.

The colour of the sample was examined quantitatively using a Konica Minolta CR-410 (Konica Minolta, Japan) Chromameter instrument. From the measurement, the lightness (L*), redness (a*), and yellowness (b*) parameters were obtained. The colour parameters were used to calculate the browning index by entering them into the formula (Kar, Mujumdar, & Sutar, 2019). The method for calculating the browning index was described as shown in Equations 3 and 4.

$$Browning\ Index = \frac{100(x-0.31)}{0.172} \quad (3)$$

Where x is signified as;

$$x = \frac{(a^{*}+1.75L)}{(5.645L+a^{*}-3.012b^{*})} \quad (4)$$

The AOAC (2005) method was applied to determine the amounts and percentages of different components in the kefir powder. The testing was performed using dried samples, and to determine the moisture level, a portion of the sample was placed in an oven set at 105 °C and left for 16 hours. The ash content was determined by placing the sample in a furnace heated to 550 °C and maintaining it for 5 hours. The Kjeldahl method was used to analyse protein content with a conversion factor of 6.25. The Soxhlet extraction method with petroleum benzene solvent was used to analyse the crude fat content. Water activity in the powder sample was analysed using the Aqualab Type-4TE Water Activity Meter (Aqualab, USA). The total plate count (TPC) method was used to enumerate total lactic acid bacteria (LAB) and yeast in the powder sample. The medium used for total LAB enumeration was MRS agar mixed with 0.15% bile salt (Boke, Aslim, & Alp, 2010). One (1) gram of kefir powder was diluted with 9 mL of distilled water as the first dilution at 10^{-1}. One mL of this solution was remixed with 9 mL of distilled water until a 10^{-7} dilution was reached. Afterwards, 0.1 mL from this last dilution was inoculated onto a Petri dish with solidified MRS agar and then incubated at 37 °C for 48 hours. The number of bacteria was determined by counting the colonies that formed. The total yeast was enumerated on malt extract agar (MEA) media, with dilutions carried out in triplicate up to the seventh dilution (10^{-7}). After a 48-hour incubation, the yeast colonies were counted using a colony counter.

3.4. Statistical Analysis

The data are presented as the means ± standard deviations (SDs). Costat software was used for statistical analysis. To compare data from more than two treatment groups, One-way analysis of variance (ANOVA) was used. This analysis was followed by Duncan's Multiple Range Test (DMRT) to determine significant differences between groups. A p-value < 0.05 indicates statistical significance.

4. RESULTS AND DISCUSSION

4.1. Microbial Viability

Spray drying offers a rapid dehydration advantage over other drying methods. The high temperatures applied to the spray drying process can be controlled to give an advantage in productivity, rapid drying process, high microbial viability, and physicochemical quality (Anandharamakrishnan & Ishwarya, 2015). Because the market value of a product depends on the established standards, the physicochemical quality and viability of microbes in the powder must be preserved. Therefore, the appropriate spray-drying process parameters were optimized such that the powder quality and viability were maintained while the rapid process rate increased productivity.

The microbial viability of the kefir powder is shown in Figure 1. The results showed that an increase in the inlet temperature did not always reduce the viability of LAB. These findings indicated that LAB viability could be maintained by balancing high inlet temperatures with a fast feed rate. Compared with T3, the lower-temperatures treatment T1 and T2 resulted in LAB viability comparable to T4. High inlet temperatures, combined with a low feed rate and a short process time, resulted in a protected LAB viability in T4, which was lower than that in T3. The LAB viability in T2 and T1 showed lower than T3 and similar to T4 due to low feed rates and longer processing times.

Atalar and Dervisoglu (2015) and Huang et al. (2017) previously reported that proper selection of inlet temperature, accompanied by a fast feed rate, was able to maintain LAB viability. Spray drying has previously been reported to maintain LAB viability (Barbosa et al., 2017). In this recent study, all the inlet temperature treatments resulted in LAB viability that still met the CODEX STAN 243-2003 (Codex Alimentarius Commission, 2018) and SNI 7552:2009 standards (National Standardization Agency of Indonesia, 2018). The other reason that LAB can maintain viability during the spray drying process is the presence of peptidoglycans on their cell walls, which prevent environmental damage. Another factor was linked to the high carbohydrate content in the fermented kefir products. Glucose, as a type of sugar, protected the biological tissues of LAB during the dehydration process (Truong, Bhandari, & Howes, 2005). Moreover, the increase in inlet temperature affected the reduction in yeast viability (Figure 1); as compared with LAB, yeast is less heat-resistant (Ridara, Muhammad, Setiawan, Riskina, & Nurjannah, 2023). The thermal tolerance of yeast is low, and it has been reported that temperatures above 50 °C significantly reduce yeast viability (Tontul et al., 2021). According to this study, not all yeast viability meets the standards for fermented milk products, with the highest inlet temperature treatment resulting in low yeast viability.

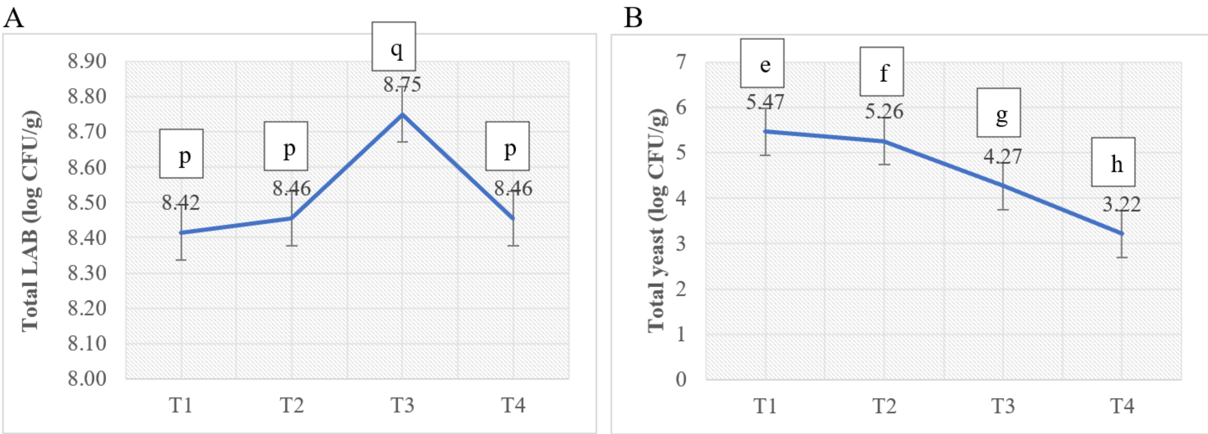

Figure 1. Total viable lactic acid bacteria (A) and yeast (B) in kefir powder produced using four different inlet temperatures (T1, T2, T3, and T4).

Note: The different letters above the data indicate significant differences ($p < 0.05$).

4.2. Yield and Physical Characteristics of Kefir Powder

Table 2 shows that variations in the inlet temperature significantly affected both the residence time and the feed rate. At high inlet temperatures, when accompanied by a high feed rate, the process was performed quickly, resulting in a short residence time. Variations in the inlet temperature did not affect the yield obtained. However, an increase in inlet temperature tended to increase yields (Table 2).

Table 2. Physical characteristics of kefir powder.

Variables	Treatment			
	T1	T2	T3	T4
Total process time (min)	$52.00^{a}\pm1.63$	$37.33^{b}\pm2.49$	$22.67^{c}\pm1.25$	$20.67^{c}\pm0.94$
Process rate (ml/min)	7.69	10.71	17.65	19.35
Yield (%)^{ns}	7.34±0.80	7.38±1.15	7.55±1.50	7.81±1.02
Wettability (min)^{ns}	1.86±0.14	1.11±1.11	1.41±0.15	2.32±1.05
Colour chromameter:				
L* (Brightness)^{ns}	90.57±0.66	90.67±1.02	90.43±0.21	88.00±1.96
a* (Red)	$2.20^{b}\pm0.08$	$1.87^{b}\pm0.40$	$2.03^{b}\pm0.21$	$3.43^{a}\pm0.19$
b* (Yellow)	$21.87^{ab}\pm1.72$	$21.47^{b}\pm2.41$	$21.33^{b}\pm0.83$	$25.37^{a}\pm0.31$
Browning index	28.50	27.63	27.66	35.75
Water activity	$0.24^{c}\pm0.01$	$0.33^{a}\pm0.01$	$0.30^{b}\pm0.00$	$0.31^{b}\pm0.00$

Note: The values are presented as the mean ± SD. Values with different superscripts within the same column are significantly different ($p < 0.05$).
ns: Non significant.

Table 2 shows that the inlet temperature treatments were ineffective in increasing product yield because the total soluble solids in the liquid kefir were similar. However, the same yield percentage indicates the same productivity (Moghbeli et al., 2019) because no material was lost during the treatment. In terms of the spray drying process, the decrease in yield is usually caused by material sticking to the container. A previous study has shown that retention time in the container affects moisture absorption by the powder (Chiou & Langrish, 2007), particularly in dairy products containing lactose. Moisture absorption due to longer processing times increased the tendency of the powder to stick to the walls of the storage chamber (Ahmad & Nguyen, 2017). Fast processing times reduce the risk of water absorption by the dry powder particles, so the application of high inlet temperatures has the potential to reduce yield loss that adheres to the container.

The wetting ability of kefir powder is defined as the time required for the powder to become completely wet. The result of the study, shown in Table 2, indicates that variations in inlet temperature did not affect the wetting ability of kefir powder. High inlet temperatures are generally known to cause protein denaturation and disrupt the hydrophobic group folds (Li, Zhao, Li, & Yu, 2021), resulting in a longer wetting time. High fat content also causes a similar effect at low inlet temperatures. Factors such as particle shape and surface morphology, which can affect the rehydration time of a material, were disregarded because of the similar spherical shape and size of the material (An & Zheng, 2025). The shape of the powdered kefir particles is shown to be spherical with a consistent particle size, creating a similar surface area.

Water activity (aw) is defined as the availability of free water in the food matrix that is vital for the growth of yeast and LAB in kefir powder. Spray-drying is an effective method for substantially reducing aw by evaporating water, as shown by the data presented in Table 2. The analysis showed that the highest aw value was recorded for T2 (0.33±0.01), followed closely by T3 (0.30±0.00) and T4 (0.31±0.00). The aw value at T3 and T4 was not different; both exhibited slightly lower aw values than T2. T1 had the lowest aw value (0.24 ± 0.01), which was directly linked to the lowest microbial viability (Figure 1). The relatively high aw values for treatments T2, T3, and T4 were related to high moisture content, which is a fundamental factor for microbial viability. This study shows that a reduction in aw could compromise the resilience of the microbial communities. Optimizing the inlet temperature during the spray-drying process is an effective strategy to minimize aw values and reduce the possibility of microbial contamination.

A high L* value approaching 100 indicates a white powder; this suggests that the powder produced by spray drying is mostly white, and the differences in inlet temperatures did not affect its brightness value. The test results presented in Table 2 show positive a* values in all the treatments, indicating a consistent tendency towards red. The highest a* values were obtained at the highest inlet temperature parameter, indicating the possibility of the Maillard reaction. Similarly, the final colour test parameter was the b* value, which was positive in all the treatments. The b* values at the highest inlet temperature differed from those of the other treatments, tending towards a dark yellow hue compared with those of the other treatments. In addition, the colour test revealed that the degree of yellow (b) and red (a) increased at an inlet temperature of 180 °C, whereas the L* value remained unchanged (Table 2). This was evidenced by the calculation of the browning index, where the highest inlet temperature tended to increase the browning index (Table 2). The relatively high browning index at low inlet temperatures was due to the low feed rate (De Oliveira et al., 2021). The Maillard reaction is estimated to begin at an inlet temperature of 180 °C, which is indicated by an increase in carbohydrate content resulting from the interaction of protein with glucose (Liu, Hedegaard, & Skibsted, 2013) oxidized fats (Seville et al., 2007; Thomsen, Lauridsen, Skibsted, & Risbo, 2005; Zamora & Hidalgo, 2005) and protein denaturation (Jones, Ruprecht, Crichton, & Kunji, 2024).

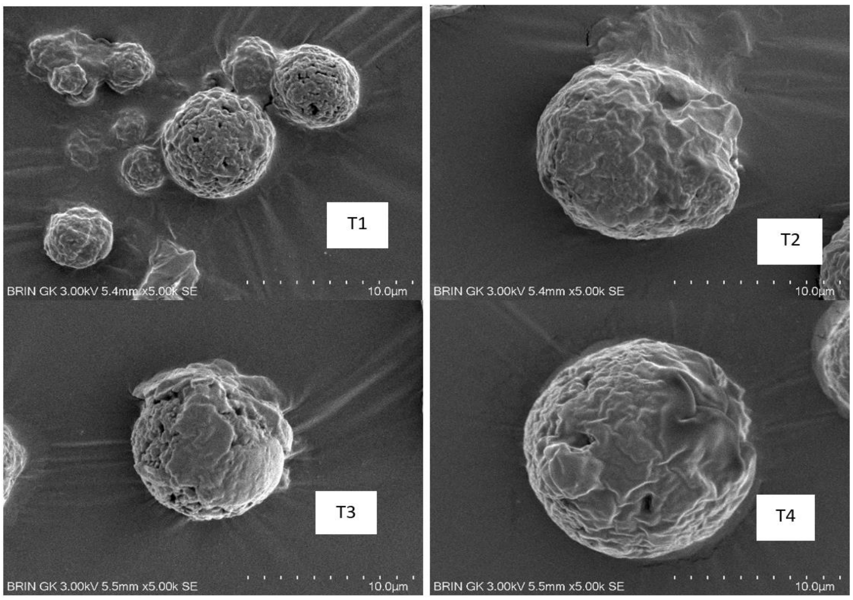

Figure 2. Morphological shape of kefir powder produced using four different inlet temperatures (T1, T2, T3, and T4) at 5000× magnification.

The SEM image at 5000× magnification in Figure 2 shows uniformly round kefir particles across all the treatments. Previous studies have indicated that atomization pressure influences particle shape and size (Foerster, Gengenbach, Woo, & Selomulya, 2016). Variations in the inlet temperature did not affect the particle shape (Figure 2). In accordance with the experimental design, the atomization conditions were kept constant across all the treatments, as there were no changes in the atomization pressure that impacted the resulting particles (Maury, Murphy, Kumar, Shi, & Lee, 2005). An image at 1000× magnification is presented in Figure 3. SEM revealed the complete shape and size diversity of the kefir powder particles. The particle size was less than 20 µm in all the treatments, namely, T1 (5.99–14.6 µm), T2 (8.14–13.4 µm), T3 (4.59–19.2 µm), and T4 (4.77–14.3 µm). Kefir powder particles had a similar spherical shape with a relatively similar diameter at all inlet temperatures. The structural description shows that the inlet temperature treatment, accompanied by feed pump rate conditioning, did not affect the shape or size of the powder particles, indicating that the atomizer pressure played a dominant role (Ahmad & Nguyen, 2017).

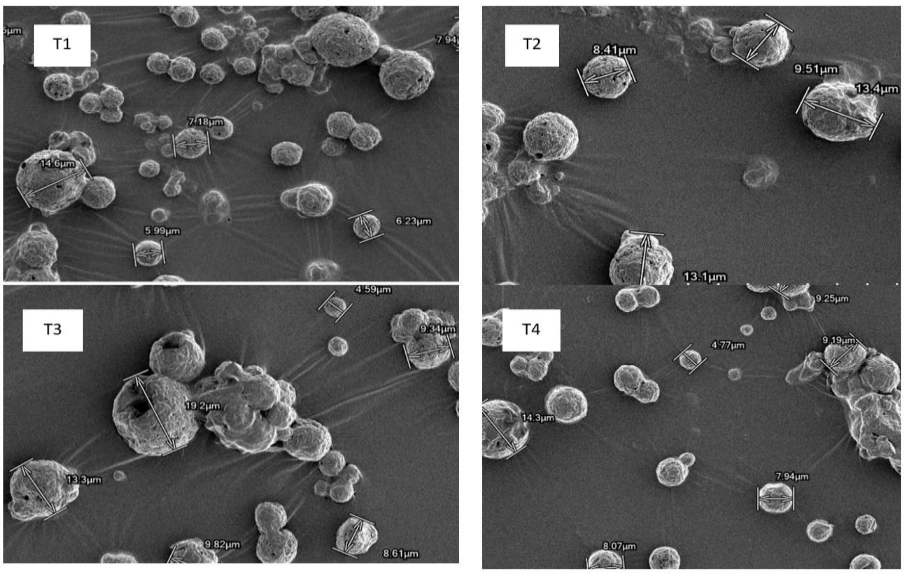

Figure 3. Morphological shape of kefir powder produced using four different inlet temperatures (T1, T2, T3, and T4) at 1000× magnification.

4.3. Nutritional Content of Kefir Powder

The water content was related to the stages of the spray drying mechanism, which included atomization of the solution into droplets, drying the droplets into particles, and collection of the powder particles (Santos et al., 2018). Dehydration occurred during both the droplet phase and the powder phase. The droplet phase occurred when the droplet met hot air, and the powder phase occurred when the collected powder was exposed to heat. Table 3 shows an insignificant difference in water content in kefir powder. This occurred when the solvent evaporating from the surface was not being adequately replaced from the centre, resulting in the formation of a thin skin layer that reduced the evaporation rate and increased the particle temperature (Al-Zoubi, Gharaibeh, Aljaberi, & Nikolakakis, 2021). The droplet phase was not considered because the outlet temperature was the same in all the treatments and did not affect the skin formation rate (Anandharamakrishnan & Ishwarya, 2015). As the solvent was pushed towards the surface to form the skin (Siemons, Politiek, Boom, van der Sman, & Schutyser, 2020), this did not affect the skin formation rate.

Table 3. Nutritional content of kefir powder produced using four different inlet temperatures.

Variables	Treatment			
	T1	T2	T3	T4
Water (%) ^{ns}	7.66±0.12	7.98±0.87	8.53±1.11	9.55±1.00
Fat (%)	24.42^{a}±2.10	23.84^{a}±2.11	17.81^{b}±1.24	13.83^{c}±0.73
Protein (%) ^{ns}	14.43±1.28	14.09±0.58	15.14±0.28	14.31±0.53
Carbohydrate (%)	46.89^{c}±2.08	47.31^{c}±0.69	51.02^{b}±1.01	54.91^{a}±1.72
Mineral (%) ^{ns}	6.60±0.28	6.78±0.41	7.40±0.36	7.50±0.72
Organic material (%) ^{ns}	93.40±0.28	93.22±0.41	92.50±0.36	92.60±0.72

Note: The values are presented as the means ± SDs. Values with different superscripts within the same column are significantly different ($p < 0.05$).
ns: Not significant.

Proteins were sensitive to the high temperatures applied during spray drying. However, heat-sensitive nutrients may be retained because of the brief and rapid exposure process (De Oliveira et al., 2021). Spray drying has been shown to maintain protein content (Felfoul et al., 2022) with a high feed rate, resulting in a high percentage of protein. Overall, Table 3 presents that variations in inlet temperature during the spray-drying process resulted in minimal changes in protein content, as the application of low outlet temperatures (66–68 °C) effectively retained the protein content (Anandharamakrishnan, Rielly, & Stapley, 2007). The protein content in all the treatments met the CODEX STAN 243-2003 and SNI 7552:2009 standards. It indicates that inlet temperature optimization is an effective means of enhancing process productivity while maintaining the quality of kefir products (Liu, Zhang, Han, Zhang, & Zhou, 2020).

High process temperatures tend to result in the release of more bonds between fat and water, leading to increased oxidized fat (Liu et al., 2020). In addition to the high process temperature, the low-fat content was also influenced by high process rates (Medina-Meza & Barnaba, 2013) in the higher inlet temperature treatments. Treatments with high process rates caused atomized liquid kefir (Amundson, Ishino, & Lindsay, 1980) to form many droplets at one time, making the drying chamber dense and leading to the absorption of a large amount of oxidized fat along with O2. Fat in droplets formed at high temperatures was oxidized and bonded with O2. Owing to the volatile nature, fat was also absorbed. This study provided information indicating that spray drying with varied inlet temperature parameters, an optimal feed flow rate, and an optimal atomization pressure was effective at breaking down fat into fatty acids, thereby reducing the fat content (Table 3).

Table 3 shows that the highest carbohydrate content was found for treatment T4 (54.91±1.72%), which corresponded to the highest inlet temperature treatment. The low-fat content influenced the carbohydrate content in treatment T4, as carbohydrates consisted of lactose and glycerol from fat breakdown. In the spray-drying process, which involved the application of high heat, fat was released from its bonds with protein and water because of protein denaturation caused by heat.

Water without dissolved solids evaporated immediately, whereas fat, having mass, decreased as a result of the process. Fat exposed to heat can be broken down into fatty acids and glycerol. The glycerol from fat breakdown contributed to the increased carbohydrate content in high-temperature processes. This was evidenced by the lower carbohydrate content in processes with lower inlet temperature treatments. Therefore, it could be concluded that variations in the inlet temperature affect the fat content.

The mineral content in kefir powder ranged from 6.60 to 7.50% (Table 3), a value similar to that previously reported by Felfoul et al. (2022). Minerals are inorganic substances that are relatively resistant to heat exposure. High temperatures in ashing tests were used to determine the mineral content. Several inorganic minerals were difficult to burn; as a result, a furnace was used to determine the ash content in food materials. The temperatures applied in the spray-drying process were far below the ashing temperature; therefore, the mineral content was not affected by the inlet temperature applied during spray drying.

The differences in mineral content were due to the sample weighing and testing processes, as the samples burnt in the furnace did not completely turn to ash (Liu et al., 2013). Incomplete combustion resulted in the ash content being higher than the actual value.

Table 3 summarizes the organic material content of the kefir powder. The organic material content did not significantly differ across all the treatments. The organic material content was calculated by subtracting the mineral content from the total 100% material. The organic material content in T1 was 93.4 ± 0.28; that in T2 was 93.22±0.41; that in T3 was 92.50±0.72; and that in T4 was 92.60±0.72%. The organic material content in all the treatments was generally similar.

5. CONCLUSION

The application of high inlet temperature, coupled with optimal outlet temperature, is effective in increasing productivity and quality of kefir powder.

The combination of an inlet temperature of 160 °C with an outlet temperature that was set at 66–68 °C is the best spray drying method to achieve high productivity and quality. High productivity is demonstrated by decreased processing time and the ability to maintain both physicochemical quality and microbial viability.

This spray drying method is suitable for producing highly nutritious kefir products with long shelf life. The effective spray drying process reported in this study needs to be compared with different outlet temperatures applied.

Funding: This study received additional funding from Lembaga Pengelola Dana Pendidikan (LPDP), Ministry of Finance of the Republic Indonesia through Riset dan Inovasi untuk Indonesia Maju (approved on 8 May 2023 with grant code RIIM-3021916683) and Program Hilirisasi Riset Strategis - Skema Pengujian Produk with grant number 001/SPK/C4/DHK/VI).
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Acknowledgement: The authors extend their sincere gratitude to Badan Riset dan Inovasi Nasional (BRIN) Indonesia for providing research facilities via E-Layanan Sains BRIN.

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