Vacuum-Dried Goat Milk Kefir: A Novel Approach to Enhancing Quality with Dextrin, Inulin, and Albumin

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Abstract. Vacuum drying is a widely used method for producing goat milk kefir powder. This technique removes moisture from fermented kefir while preserving its nutritional and probiotic properties. The production of goat milk kefir powder through vacuum drying providing an effective method to maintaining these qualities and extending shelf life. This study investigates the effects of adding dextrin, inulin, and egg albumin to improve vacuum-dried goat milk kefir's physicochemical and microbiological properties. A completely randomized design (CRD) was employed, involving four treatments: P0 (control), T1 (2% Dextrin + 2% Inulin + 3% Albumin), T2 (4% Dextrin + 4% Inulin + 6% Albumin), and T3 (6% Dextrin + 6% Inulin + 9% Albumin), each with four replicates. Key parameters analysed included pH, dissolved protein content, total plate count (TPC), and colour. The results indicated that including dextrin, inulin, and albumin significantly improved protein solubility, enhanced probiotic viability, and stabilised the product's colour. Treatment T1 (2% Dextrin, 2% Inulin, 3% Albumin) yielded the most favourable outcomes. This suggests that these additives are crucial in optimising the quality and functionality of vacuum-dried kefir powder. Overall, this study presents a promising method for enhancing kefir powder for commercial use, ensuring nutritional and sensory quality retention.

Keywords: kefir powder, functional food, shelf life.

1 Introduction

Kefir is a fermented milk product known for its probiotic content and associated health benefits, such as improving gut health, enhancing the immune system, and contributing to overall nutrition. Traditionally made from cow's milk, kefir can also be produced using goat's milk, which has several distinct advantages [1]. Goat milk is known for its easier digestibility due to smaller fat globules, lower lactose content, and bioactive compounds, making it an excellent alternative for individuals with lactose intolerance or sensitivity to cow's milk [2][3].

However, converting liquid kefir into a powdered form introduces challenges in maintaining the integrity of its probiotics and ensuring that the resulting product retains its nutritional and sensory qualities. Drying kefir can lead to protein denatura-

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tion, a loss of microbial viability, and physical changes such as clumping or colour degradation. To address these issues, novel approaches are needed to preserve the beneficial properties of kefir while extending its shelf life. In the manufacturing process, texture characteristics are quality factors that affect appearance, mouthfeel, and overall desirability[4].

One such approach is the incorporation of additives such as dextrin, inulin, and egg albumin in the vacuum drying process [5]. These additives serve multiple functions: dextrin acts as a carrier and bulking agent, improving powder consistency and preventing clumping; inulin, a prebiotic fibre, enhances microbial viability by providing a nutrient source for probiotics and contributes to better texture and solubility; and egg albumin, a stabilising protein, helps protect other proteins from denaturation during the drying process and enhances the overall texture and rehydration properties of the final product. In alignment with this strategy, the use of plant-derived starches such as canna starch is also gaining attention due to their functional components. Canna starch has been reported to contain appreciable levels of dietary fibre, which may contribute to digestive health and exhibit prebiotic potential by selectively stimulating the growth of beneficial gut microbiota [6], thereby supporting the overall functionality of synbiotic formulations.

This study investigates how varying concentrations of dextrin, inulin, and egg albumin affect vacuum-dried goat milk kefir powder’s physicochemical properties and microbial viability. Specifically, we aim to evaluate their impact on critical parameters such as pH, dissolved protein content, total plate count (TPC), and colour. By optimising these additives, we seek to develop a method that enhances the quality of kefir powder, ensuring its stability and nutritional integrity for commercial applications. This research contributes to the growing interest in functional foods and the development of powdered kefir products that retain the health benefits of the original liquid form while offering a powder's convenience and extended shelf life. We hypothesise that including dextrin, inulin, and egg albumin will significantly improve goat milk kefir powder’s functional and sensory properties, making it a viable option for consumers and producers.

2 Materials and Methods

2.1 Materials

The study utilised fresh goat milk kefir, dextrin powder, distilled water, 70% alcohol, and a 0.9% NaCl solution. The study utilised dextrin powder (food grade, Sigma-Aldrich, USA), inulin (≥90% purity, Chicory-derived, Sigma-Aldrich, USA), and egg albumin (analytical grade, Merck, Germany). It employed Plate Count Agar (PCA) for microbial analysis and Buffered Peptone Water (BPW) for sample preparation, along with pH seven and pH four buffer solutions for calibration. Essential tools included a vacuum dryer for dehydration, a pH meter for acidity measurement, an autoclave for sterilisation, and a Laminar Air Flow (LAF) cabinet for aseptic work. Additional equipment comprised an incubator, spectrophotometer, micropipettes, Petri dishes, test tubes, Erlenmeyer flasks, a colour reader, analytical balance, Whatman filter paper, and a centrifuge. These materials and tools were crucial for the experimental procedures and analyses.

2.2 Methods

This study employed a Completely Randomized Design (CRD) with four treatments and four replicates to evaluate the effects of varying concentrations of dextrin, inulin, and egg albumin on the quality of goat milk kefir powder produced through vacuum drying. The methodology included kefir fermentation, preparation of kefir powder, vacuum drying, and the analysis of pH, protein content, microbial viability, and colour.

Fresh goat milk was pasteurised at 72°C for 15 seconds and then cooled to 25°C. Kefir grains were added at a concentration of 5% (w/v), and the mixture was allowed to ferment at room temperature (20-25°C) for 24 hours, with continuous monitoring for pH drop. After fermentation, the kefir was divided into four groups: P0: No additives (control), T1: 2% dextrin, 2% inulin, and 3% albumin, T2: 4% dextrin, 4% inulin, and 6% albumin, and T3: 6% dextrin, 6% inulin, and 9% albumin, respectively. Each treatment was vacuum-dried at a controlled and fixed temperature of 42°C. The temperature was continuously monitored throughout the drying process. Drying was continued until the moisture content was reduced to below 5%. Following drying, the samples were milled and stored in airtight containers.

The pH value was measured using a digital pH meter calibrated with buffer solutions [7]. Protein content was quantified using the Lowry method and spectrophotometry at 660 nm [8]. Microbial viability was assessed using Plate Count Agar. Serial dilutions were prepared up to 10^{-7} using Buffered Peptone Water. 1 mL of each dilution was plated on PCA in duplicate and incubated at 37°C for 48 hours. Colony-forming units (CFU) were counted and expressed as log CFU/g. Colour was measured using a 3nh CR6 Color Reader (3nh, Chine), calibrated with standard white and black tiles. Measurements were expressed in L* (lightness), a* (red-green), and b* (yellow-blue) values values. All data obtained were analysed using ANOVA and Duncan's Multiple Range Test (DMRT) with a significance level of $p < 0.05$. This methodology effectively evaluated the impacts of dextrin, inulin, and egg albumin on the quality and stability of vacuum-dried goat milk kefir powder.

3 Results and Discussion

3.1 Physicochemical Quality of Goat Milk Kefir Powder

The addition of dextrin, inulin, and albumin significantly influenced the physicochemical characteristics of goat milk kefir powder. While pH remained consistent across treatments, higher concentrations of additives (T2 and T3) led to lower protein solubility, likely due to excessive protein aggregation. In terms of colour, higher concentrations of dextrin and inulin resulted in a lighter, less red, and less yellow product, which may be more visually appealing to consumers. The optimal additives balance appears in the T1 treatment (2% dextrin, 2% inulin, and 3% albumin), where protein solubility remained high, and the color characteristics were acceptable.

Table 1. Effect of Additive Concentration on Physicochemical Properties of Kefir Powder

Sample	Parameters				
	pH	Dissolved Protein (mg/ml)	Color		
			L	a*	b*
T0: No additives (control)	4.18 ± 0.01	4.97 ± 0.53	84.61 ± 1.31^{a}	2.83 ± 0.11^{a}	18.61 ± 1.29^{a}
T1: 2% dextrin, 2% inulin, and 3% albumin,:	4.16 ± 0.01	5.07 ± 0.28	75.49 ± 5.02^{a}	2.68 ± 0.20^{a}	16.73 ± 0.75^{a}
T2: 4% dextrin, 4% inulin, and 6% albumin, and T3	4.13 ± 0.03	4.65 ± 0.55	88.99 ± 0.77^{b}	1.91 ± 0.86^{ab}	13.71 ± 1.49^{ab}
T3 = 6% dextrin, 6% inulin, and 9% albumin	4.12 ± 0.03	4.02 ± 0.09	87.95 ± 0.37^{b}	1.65 ± 0.19^{b}	12.12 ± 1.06^{b}

$^{a-b}$Common superscript indicates a significant difference ($P < 0.05$)

pH Value. The pH values across all treatments remained relatively similar, ranging from 4.12 to 4.18, with no significant differences between treatments, indicating that adding dextrin, inulin, and albumin did not dramatically affect the acidity of the kefir powder. This consistent pH level is expected, as the fermentation process of kefir produces lactic acid, resulting in an overall acidic product regardless of the presence of additives. The slight decline in pH in the T2 and T3 treatments compared to the control (T0) might indicate that higher concentrations of dextrin, inulin, and albumin slightly influenced the buffering capacity of the mixture but not enough to cause a significant shift in acidity.

Proteins are sensitive to pH changes, and their solubility depends on the pH of the medium. When the pH approaches proteins' isoelectric point (pI), their solubility decreases, causing them to precipitate or coagulate. For milk proteins like casein, the isoelectric point is around pH 4.6. In kefir, a lower pH can cause proteins to aggregate and reduce their solubility, which may affect the texture and consistency of the final product[9].

pH can also impact the colour of the product. For instance, a lower pH in dairy products can cause proteins to denature and aggregate, which might result in changes to the product's appearance, making it look more opaque or whitish. In acidic environments, some pigments (if present) may change colour due to protonation, which could alter the overall appearance of the kefir powder[10].

Dissolved Protein. Dissolved protein levels showed variation across treatments. The control (T0) had a 4.97 mg/ml dissolved protein content, while the highest protein solubility was observed in T1 (5.07 mg/ml). However, as dextrin, inulin, and albumin concentration increased in T2 and T3, the dissolved protein content decreased significantly, reaching 4.02 mg/ml in T3. This suggests that higher albumin (a stabilising protein) might have led to protein-protein interactions or aggregation, reducing overall solubility. Conversely, in the lower albumin (T1) concentration, the additives likely improved protein stability without leading to excessive protein aggregation, thus maintaining or slightly improving solubility. The reduction in solubility in T2 and T3 may be due to excessive cross-linking or matrix formation, which trapped proteins and prevented them from dissolving effectively[11].

Protein solubility is highly dependent on pH. As mentioned, proteins tend to precipitate or coagulate when the pH approaches their isoelectric point. The dissolution of proteins in water or other solvents can also buffer the pH of the solution, depending on the types of amino acids present. Proteins influence the colour of dairy products by affecting light reflection. As proteins denature and aggregate, they can cause changes in the product's opacity, potentially altering the colour. More dissolved proteins usually make the product appear brighter or more translucent, while aggregated proteins might make it look cloudy or dull[12].

Color (L, a, b* values). The treatments significantly affected the L value* (lightness) of the kefir powder. The control sample (T0) had an L* value of 84.61, while the highest lightness was observed in T2 (88.99) and T3 (87.95), both of which were significantly lighter than T0 and T1 (75.49). This increase in lightness with higher concentrations of additives (particularly dextrin) suggests that these components contributed to a whiter, more uniform appearance by possibly creating a smoother, more reflective surface. As a carrier and drying aid, Dextrin likely helped reduce browning or colour degradation during drying, leading to higher lightness in T2 and T3. T1, with the lowest lightness value, might have had less efficient drying or a more varied surface texture due to the lower concentrations of additives.

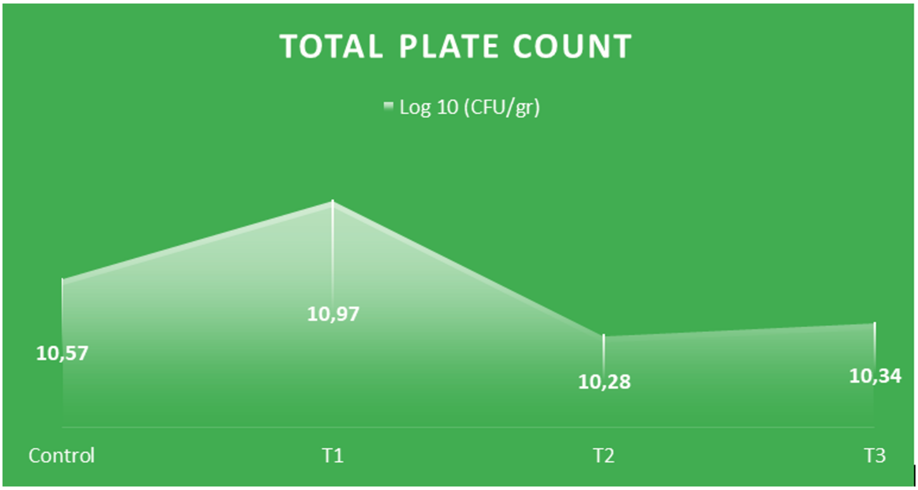
The a* (red-green) and b* (yellow-blue) values showed a general decrease as dextrin, inulin, and albumin concentrations increased. In the control sample (T0), the a* value was 2.83, indicating a slight red hue, while in T3, the a* value decreased to 1.65, showing a reduction in redness. Similarly, the b* value, which indicates yellowness, decreased from 18.61 in the control to 12.12 in T3. This reduction in a* and b* values suggests that higher concentrations of additives, especially dextrin and inulin, may have reduced browning and yellowing during drying. This effect is significant for ensuring a visually appealing kefir powder, as lighter colours are often associated with freshness and quality in powdered products[5].

Changes in pH can alter the colour of food products. In kefir, a lower pH might cause proteins to coagulate, changing from a translucent to a more opaque, white appearance. If any pigments are present in the product, pH changes could also affect their stability and result in a noticeable colour shift[13].

The product's colour can be affected by the state of the proteins. Highly soluble proteins contribute to a more transparent or more translucent product, while aggregated proteins tend to scatter light, making the product look more opaque or white. Changes in protein solubility, induced by factors like pH or heat, can lead to noticeable[14].

3.2 Microbial Viability of Goat Milk Kefir Powder

The total plate count (TPC), as shown in the Figure 1, represents the microbial viability of goat milk kefir powder, explicitly indicating the number of viable probiotics (log CFU/gr) in the different treatments. The control treatment (P0) exhibited a TPC of 10.57 log CFU/gr, which serves as the baseline for comparison against treatments that included varying concentrations of dextrin, inulin, and albumin. The control group (P0), which had no additives, showed the lowest microbial count at 10.57 log CFU/gr. This means that without additives, the probiotic bacteria in the kefir powder were less protected during the vacuum drying process. The absence of protective agents like dextrin and inulin likely led to a more significant loss of viable microorganisms. This loss happened because of the stress from drying, including heat and lack of moisture.



Control : No additives, T1= 2% dextrin + 2% inulin + and 3% albumin, T2 = 4% dextrin + 4% inulin + 6% albumin, and T3 = 6% dextrin + 6% inulin + 9% albumin

Fig. 1. Microbiological Quality of Goat Milk Kefir Powder with Different treatment

In treatment T1, which included 2% dextrin, 2% inulin, and 3% albumin, the total plate count rose significantly to 10.97 log CFU/g, the highest of all treatments. This combination effectively protected probiotic bacteria during vacuum drying. Dextrin likely served as a carrier and moisture absorber, inulin provided essential nutrients, and albumin helped stabilise and protect the bacteria from heat and stress. In T2, containing 4% dextrin, 4% inulin, and 6% albumin, the total plate count (TPC) dropped to 10.28 log CFU/g, indicating reduced microbial viability compared to Treatment 1 (T1). The higher concentrations may have led to less effective protection, as excessive albumin could cause over-encapsulation and create a denser matrix that hinders survival [15].

Furthermore, increased dextrin and inulin levels might affect water activity or osmotic balance, compromising probiotic viability during drying and storage. Treatment T3 (6% dextrin, 6% inulin, and 9% albumin) showed a slight increase in total viable count (TPC) to 10.34 log CFU/g compared to T2, but it remained lower than T1. This suggests that higher concentrations of additives don't necessarily improve microbial survival. Increased concentrations may interact negatively, affecting inulin's availability as a prebiotic or altering the powder's structure. This leads to a denser matrix that limits oxygen and nutrient exchange needed for probiotic survival during drying. [16]. Inulin, a prebiotic fiber used in T1, T2, and T3, is not only a source of dietary fiber but also feeds beneficial gut bacteria, promoting their growth and activity. The synergy between prebiotics (inulin) and probiotics (from kefir) can create a synbiotic effect, further enhancing gut health and improving glucose metabolism [17].

The data demonstrate that the combination of dextrin, inulin, and albumin plays a significant role in protecting the viability of probiotic bacteria in vacuum-dried goat milk kefir powder. The highest microbial viability was achieved with the T1 treatment (2% dextrin, 2% inulin, and 3% albumin), suggesting that this concentration of additives provides an optimal balance for preserving probiotic count. Higher concentrations, as seen in T2 and T3, resulted in lower TPC, likely due to interactions between the additives that could affect the drying efficiency or probiotic viability. Therefore, to maximise the microbial quality of kefir powder, moderate concentrations of additives, such as those in T1, are more beneficial than higher concentrations.

4 Conclusion

This study shows that adding dextrin, inulin, and egg albumin improves vacuum-dried goat milk kefir powder. These ingredients help proteins dissolve, increase probiotic survival, and stabilize color. The best results came from the T1 treatment with 2% dextrin, 2% inulin, and 3% egg albumin. Higher amounts in T2 and T3 led to lower plate counts, likely affecting probiotic survival. Overall, this research offers an effective way to produce stable, high-quality kefir powder for commercial use.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. A. K. Umam, L. E. Radiati, A. M. Wati, M. R. Rifano, and D. A. A. Putri, "Influence of different prolonged aging times on the goat milk kefir quality," Developing Modern Livestock Production in Tropical Countries, pp. 158–162, 2023, doi: 10.1201/9781003370048-38.
2. M. A. Farag, S. A. Jomaa, A. A. El-wahed, and H. R. El-seedi, "The many faces of kefir fermented dairy products: Quality characteristics, flavour chemistry, nutritional value, health benefits, and safety," Feb. 01, 2020, MDPI AG. doi: 10.3390/nu12020346.

3. A. K. Umam, L. E. Radiati, N. P. Aryudya, M. R. Rifano, and R. . Ramadhan, “Influence Lactation Stage On Milk Quality Of Small Holders Etawah Crossbreed Goats,” AGRIOVET, vol. 5, no. 2, pp. 1–10, 2023.
4. A. Umam, M. J. Lin, L. E. R, and S. Y. Peng, “The Utilization of Canna Starch (Canna Edulis Ker) As An Alternative Hydrocolloid on the Manufacturing Process of Yogurt Drink,” Jurnal Ilmu dan Teknologi Hasil Ternak, vol. 13, no. 1, pp. 1–13, Apr. 2018, doi: 10.21776/ub.jitek.2018.013.01.1.
5. S. Kef and S. Arslan, “The effects of different dietary fiber use on the properties of kefir produced with cow’s and goat’s milk,” J Food Process Preserv, vol. 45, no. 6, Jun. 2021, doi: 10.1111/jfpp.15467.
6. A. Khoirul Umam, M.-J. Lin, L. E. Radiati, and S.-Y. Peng, “The Capability of Canna edulis Ker Starch as Carboxymethyl Cellulose Replacement on Yogurt Drink During Cold Storage,” Anim Prod, vol. 20, no. 2, pp. 109–118, 2018.
7. A. K. Umam, L. E. Radiati, A. Susila, and R. N. Hapsari, “Chemical and microbiological quality of fermented goat meat dendeng with different levels of L. plantarum,” in IOP Conference Series: Earth and Environmental Science, Institute of Physics Publishing, Dec. 2019. doi: 10.1088/1755-1315/387/1/012012.
8. L. E. Radiati, A. K. Umam, A. Susilo, and A. A. Thoifi, “Effect of Lactobacillus plantarum Concentration Level on Physicochemical Properties of Fermented Goat Meat Dendeng,” in IOP Conference Series: Earth and Environmental Science, Institute of Physics Publishing, Jun. 2020. doi: 10.1088/1755-1315/478/1/012038.
9. G. Shu, L. Ma, L. Chen, M. Guo, Y. Guo, and H. Chen, “Goat milk Kefir with ACE inhibitory activity: Preparation and storage stability evaluation,” J Food Process Preserv, vol. 44, no. 5, May 2020, doi: 10.1111/jfpp.14417.
10. X. Shi, H. Chen, Y. Li, J. Huang, and Y. He, “Effects of kefir grains on fermentation and bioactivity of goat milk,” Acta Universitatis Cibiniensis - Series E: Food Technology, vol. 22, no. 1, pp. 43–50, Aug. 2018, doi: 10.2478/aucft-2018-0005.
11. H. Rizqiati, N. Nurwantoro, S. Susanti, and M. I. Y. Prayoga, “The effects of dextrin concentration as filler on physical, chemical, and microbiology properties of powdered goat milk kefir,” J Indones Trop Anim Agric, vol. 46, no. 2, pp. 145–153, Jun. 2021, doi: 10.14710/jitaa.46.2.145-153.
12. J. J. Izquierdo-González, F. Amil-Ruiz, S. Zazzu, R. Sánchez-Lucas, C. A. Fuentes-Almagro, and M. J. Rodríguez-Ortega, “Proteomic analysis of goat milk kefir: Profiling the fermentation-time dependent protein digestion and identification of potential peptides with biological activity,” Food Chem, vol. 295, pp. 456–465, Oct. 2019, doi: 10.1016/j.foodchem.2019.05.178.
13. K. K. Solanki and B. C Ghosh, “Process optimization of fortified sweetened milk kefir,” Indian Journal of Dairy Science, vol. 74, no. 2, pp. 124–130, Jun. 2021, doi: 10.33785/ijds.2021.v74i02.004.
14. S. M. Sadewi, N. Nurhasanah, S. Sudibyo, N. Windayani, A. A. Kiswandono, and H. Satria, “Antioxidant and Antibacterial Activities of Curd and Whey Kefir Produced from Etawa Goat Milk,” Journal of Multidisciplinary Applied Natural Science, vol. 4, no. 1, pp. 139–145, Jan. 2024, doi: 10.47352/jmans.2774-3047.200.
15. P. Glibowski and E. Zielińska, “Physicochemical and sensory properties of kefir containing inulin and oligofructose,” Int J Dairy Technol, vol. 68, no. 4, pp. 602–607, Nov. 2015, doi: 10.1111/1471-0307.12234.
16. A. Khoirul Umam, L. Eka Radiati, K. Hutomo Putra Suwondo, and S. Nur Kholidah, “Study of Antioxidant Activity, Peptides, and Chemical Quality of Goat Milk Kefir on the

Different Post-Acidification Periods During Cold Storage," 2022. [Online]. Available: www.elsevier.com/locate/foodres
17. S. Susanti, N. Nurwantoro, J. J. Elto, T. Nugroho, A. E. Suryani, and H. Rizqiati, "Preclinical study of goat milk kefir as an antihyperglycemic food," Functional Foods in Health and Disease, vol. 12, no. 12, pp. 705–712, Dec. 2022, doi: 10.31989/ffhd.v12i12.987.