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The Impact of Storage Duration and Elevated Temperature on the Biological and Chemical Characteristics of Whole Milk Powder

Hussein Ali Shaghathi^{ID}*, Rawia Mahmood Yousif, Asmaa Ali Awad

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Abstract

A total of 45 Whole milk powder(WMP) samples from the same brand and batch were collected and tested pre and post-storage under closed conditions at 45–50 °C. during 60, 90, 120, and 150-day intervals. For the chemical indicators of the WMP, there were no significant differences in the content of fat during the different storage intervals, as the fat value was 30.00–29.99%, while the protein percent was 23.23% and did not change significantly during the storage at 60, 90, 120, and 150 days respectively. On the other hand, significant differences occurred in the moisture content, where the moisture value ranged from 2.55–2.56% as a reference reading, 2.57–2.59% after 60 days, 2.56–2.58% after 90 days, 2.70–2.71% after 120 days, and 2.76–2.81% after 150 days, respectively. Significant differences in the acidity values were obtained the results of the reference reading value ranged between 13.60–13.80 ml, 13.80–14.20 ml after 60 days, 14.20–14.40 ml after 90 days, 14.36–14.40 ml after 120 days, and 14.80–15.20 ml after 150 days, respectively. The results of the microbial profile revealed that the total viable count TVC showed a significant difference at 60, 90, 120, and 150 days. However, there are no significant differences found between the 90 and 120 days. Testing for pathogenic indicators (*Salmonella*, *E. coli*, and *Staphylococcus aureus*) clarify their absence. We determined that elevated storage temperatures of 45–50°C directly affect the quality of whole milk powder, specifically regarding moisture content, acidity, and total viable count, which increase with prolonged storage duration.

Keywords: Temperature, Biochemical, Milk powder, Storage, Acidity, SNF

1. Introduction

Whole milk powder (WMP) is an essential food for growth and a rich source of essential elements such as protein, fat, calcium, and other nutrients (Lambrini *et al.*, 2021). Despite its healthy components, the scientific community has been progressively challenging and investigating the importance of milk and dairy products in the human diet (Zhang *et al.*, 2021). However, seasonality frequently affects the production of raw milk, making it challenging to guarantee production continuity (Felfoul *et al.*, 2021). It's made by evaporating the water content from whole milk. This process results in a fine, powdery substance that retains the nutritional benefits of liquid milk, including proteins, vitamins, and minerals (Achaw & Danso-Boateng, 2021). WMP is often

used in baking and cooking, and as a convenient alternative to fresh milk, especially in regions where refrigeration is limited. It has a longer shelf life compared to liquid milk and can be reconstituted by adding water. This makes it a versatile ingredient in various recipes, from creamy soups and sauces to desserts and beverages (Schons *et al.*, 2024).

1.1. Temperature effects on nutritional content

- 1.1.1. **Lipid Oxidation:** Increased temperatures (e.g., 55°C) lead to higher rates of lipid oxidation. This leads to the creation of bad volatile substances and destroys essential fatty acids.
- 1.1.2. **Vitamin Degradation:** Vitamins, particularly those sensitive to heat, degrade more rapidly at elevated temperatures, impacting the

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nutritional profile of the milk powder (Thomsen *et al.*, 2005).

1.2. Shelf-life considerations

- 1.2.1. Storage at lower temperatures (25–30°C) exhibits a longer shelf life, estimated at 8–12 months (Jiang *et al.*, 2021). They may also slow down the crystallization of lactose, which can affect the texture and solubility of the milk powder over time (Goff *et al.*, 2022).
- 1.2.2. Maintaining low water activity is critical because it decreases both lipid oxidation and browning processes, hence increasing shelf life (Hedegaard & Skibsted, 2024).
- 1.2.3. The microbial composition of WMP can be modified by the microbial population of raw milk, the supplements, and concentration after heat treatment (Wedel *et al.*, 2022). Microbial organisms are the major causes of spoilage of dairy products with Gram-negative psychrotrophs, coliforms, lactic acid bacteria, yeasts, and molds being the most commonly known (Obinna, 2023). It has been proved that among many other organisms, some bacteria found in milk are potential threats to public health and these include courses like *Salmonella spp.*, Pathogenic strains of *Escherichia coli*, and enterotoxigenic strains of *Staphylococcus aureus* (Hassani *et al.*, 2022). Therefore, the microbial investigation of WMP cannot be over-emphasized. Microbial quality analysis is important for the evaluation of its quality and safety for human consumption.

Adherence to standards, specifications, and regulatory compliance regarding pathogenic bacteria of public health significance in milk has been a significant concern since the inception of the dairy industry, as numerous diseases can be transmitted through milk products, particularly raw or unpasteurized milk, which has garnered increased scrutiny as a primary vector for pathogen transmission (Ntuli *et al.*, 2023).

Due to the high temperatures in Iraq throughout the summer, stored food products are exposed to extreme conditions that may cause rotting or changes in the qualitative traits of the foods stored in warehouses. The current study aims to report the impact of high storage temperature on the biochemical shelf-life indicators of whole milk powder.

2. Materials and methods

2.1. Sampling and study design

Forty-five WMP samples from the same brand and batch were collected and transferred to the laboratory,

where they were separated into five groups of nine samples. The first set was analyzed as pre-reference samples, while the other 4 groups were kept in closed conditions at a temperature of 45–50°C. Tests were performed at 60, 90, 120, and 150 days respectively.

2.2. Qualitative tests

The tests were selected based on the criteria of the Iraqi standard specification. IQS 608-5:2022 for chemical tests, 2270-3, and 2270-5 for microbiological analysis.

2.3. Chemicals

If not specified, all chemicals were analytical grade. All dilutions were done using double deionized water (Milli-Q Millipore 18.2 M Ω cm⁻¹ resistivity). Produced inside the laboratory, sulfuric acid 98%, NaOH 0.1 %, Isoamyl alcohol, and hydrochloric acid 0.1%, Merck, Germany.

2.4. Chemical composition of WMP

Protein, fat, moisture, and acidity were performed as chemical indicators to assess the quality of the samples. The powder was dispersed in water with mechanical agitation for 5–10 min until all the milk solids were dissolved.

2.5. Determination of protein

The protein was determined using the Kjeldahl Method as described in (AOAC International, 2016).

2.5.1. Digestion of samples

Behrotest InKjel digestion unit\Germany was performed to digest the WMP samples, The samples are heated directly utilizing the infrared heaters. At 130 °C the digestion mixture was clear.

2.5.2. Distillation

Behro test distillation unit\Germany was used to analyze total nitrogen.

2.5.3. Titration

The collected mixture from the previous distillation was titrated until the endpoint reached a color change to pink. The total nitrogen was converted to "protein" by using a factor of 6.38.

2.6. Determination of fat

The determination of fat content was done according to the Gerber method (AOAC International, 2023) milk was weighed into to Gerber butyrometer

containing H₂SO₄. Isoamyl alcohol is added, and the butyrometer content is aggressively agitated to dissolve crude and release fat. Centrifugation is used to isolate fat, which is then measured using the Gerber butyrometer's graded part.

2.7. Determination of moisture

The sample is dried to a constant weight at 102 ± 2°C, and the weight loss is recorded as moisture.

The method described here has been followed by (STANDARD, 2023).

2.8. Determination of acidity

Titrate acidity was determined according to ISO 6091 | IDF 86:2010 standard method (ISO, 2010) of potentiometric titration using an inoLab pH meter (Wissenschaftlich-Technische Werkstätten GmbH [WTW], Germany) with a WTW Sen-Tix 81 glass combination electrode. Weighing (500/*w*) ± 0,01 g of the test sample into the conical flask, *w* being the solids-not-fat of reconstituted milk with 50 mL of distilled water, stirred, and titrated with 0.1 N sodium hydroxide solution until the equivalence point (pH = 8.4) was reached. The titratable acidity *V*_{ta} is given by the Eq. (1).

$$V_{ta} = 2V \quad (1)$$

where *V* is the volume, in milliliters, of the sodium hydroxide solution.

2.9. Solid non-fat (SNF)

Solid non-fat (SNF) is calculated according to the Eq. (2).

$$SNF = 100 - (F + M) \quad (2)$$

F is the Fat % and *M* is the Moisture% (ISO, 2010)

2.10. Determination microbial profile

For biological tests, the methods listed below were used:

2.9.1. Sample preparation ICMSF (ICMSF, 1978)

2.9.2. TVC ISO 4833-1(4833-1 ISO, 2013)

2.9.3. *Salmonella* ISO 16649-3 (ISO, 2013)

2.9.4. *E Coli* ISO 11866 (ISO, 2004)

2.9.5. *S. aureus* ISO 6888-1 (ISO, 2021).

2.11. Statistical analysis

To assess the impact of numerous factors on research parameters, the IBM SPSS Statistics 29.0.2.0 for the Microsoft Windows program was used. To compare means, the least significant difference is the -LSD test and analysis of variance (ANOVA) (Armonk, 2023).

3. Results

After the end of the storage times under the fixed temperature conditions as mentioned above, The following findings were achieved as mentioned in Tables 1 to 5.

3.1. Fat

From Table 1 The results were statistically analyzed in probability value ($P \leq 0.05$) between the different storage times where the fat value does not have a significant difference through the storage times where the values ranged from 30.00% to 29.99% for storage at 60, 90, 120, and 150 Days respectively. All times (60, 90, 120, and 150 days) do not differ significantly from the reference reading under the probability value ($P \leq 0.05$). The change is almost non-existent, which indicates extreme stability in the measurements.

Table 1. Fat content of WMP samples (Mean ± Standard deviation for *n* = 3).

Reference	60 Day	90 Day	120 Day	150 Day
30.00 ± 0.00 ^{Aa}	29.90 ± 0.05 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}
30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}
30.00 ± 0.00 ^{Aa}	29.90 ± 0.05 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}
30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}
30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}
30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	29.90 ± 0.05 ^{Aa}	30.00 ± 0.00 ^{Aa}
30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}
30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}
30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}	30.00 ± 0.00 ^{Aa}

^A Different capital letters in the same row refer to significant differences within storage times $P \leq 0.05$.

^a Different small letters in the same column refer to significant differences within the samples $P \leq 0.05$.

Table 2. Protein content of WMP samples (Mean $\pm$ Standard deviation for $n = 3$).

Reference	60 Day	90 Day	120 Day	150 Day
23.58 $\pm$ 0.16 ^{Aa}	23.23 $\pm$ 0.16 ^{Ba}	23.23 $\pm$ 0.16 ^{Ba}	23.23 $\pm$ 0.00 ^{Ba}	23.23 $\pm$ 0.00 ^{Ba}
23.23 $\pm$ 0.16 ^{Ab}	23.01 $\pm$ 0.11 ^{Bb}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}
23.23 $\pm$ 0.16 ^{Ab}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}
23.23 $\pm$ 0.00 ^{Ab}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}
23.23 $\pm$ 0.00 ^{Ab}	23.01 $\pm$ 0.11 ^{Bb}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}
23.23 $\pm$ 0.00 ^{Ab}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}
23.23 $\pm$ 0.00 ^{Ab}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}
23.58 $\pm$ 0.16 ^{Aa}	23.23 $\pm$ 0.00 ^{Ba}	23.23 $\pm$ 0.00 ^{Ba}	23.23 $\pm$ 0.00 ^{Ba}	23.23 $\pm$ 0.00 ^{Ba}
23.23 $\pm$ 0.00 ^{Ab}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}	23.23 $\pm$ 0.00 ^{Aa}

^{AB} Different capital letters in the same row refer to significant differences within storage times $P \leq 0.05$.

^{ab} Different small letters in the same column refer to significant differences within the samples $P \leq 0.05$.

3.2. Protein

From Table 2 The results were statistically analyzed in probability value ($P \leq 0.05$) between the different storage times where the protein value does not have a significant difference through the storage times where the values ranged from 23.58% to 23.01% for storage at 60,90,120, and 150 Days respectively. All times (60, 90, 120, and 150 days) do not differ significantly from the reference reading.

3.3. Moisture

From Table 3 The results were statistically analyzed in probability value ($P \leq 0.05$) between the different storage times where the moisture value ranged from 2.55–2.56% as a reference reading, 2.57–2.59% after 60 days, 2.56–2.58% after 90 days, 2.70–2.71% after 120 days, and 2.76–2.81% after 150 days, respectively. All periods (60, 90, 120, and 150 days) differ significantly from the reference reading, where the largest difference was recorded at 150 days Fig. 1.

3.4. Titrable acidity

From Table 4 The results were statistically analyzed in probability value ($P \leq 0.001$) the reference reading value ranged between 13.60–13.80, 13.80–14.20 after 60 days, 14.20–14.40 after 90 days, 14.36–14.40 after 120 days, and 14.80–15.20 after 150 days, respectively. All periods of 60, 90, 120, and 150 days differed significantly from the reference reading, with the largest difference recorded at 150 days Fig. 2.

3.5. Total viable count (TVC)

From Table 5, the results showed significant differences between the groups for the times of 60, 90, 120,

and 150 days compared to the reference reading ($P \leq 0.05$). Significant differences were also shown between the groups themselves, except for the 90 and 120-day groups, where there were no significant differences Fig. 3.

The Detection of pathogenic indicators *Salmonella*, *E-coli*, and *Staphylococcus aureus* was tested in WMP samples the results revealed the absence of these pathogenic microbes and these results were compatible with the Iraqi standards specifications.

4. Discussion

The protein and fat content of milk powder stays fairly constant over long storage times at high temperatures despite variations in moisture content. The low moisture level of milk powder contributes to its stability, allowing these macronutrients to be preserved longer. However, factors, like the quality of the milk powder and storage conditions, might still influence its overall quality and nutritional worth. This stability may come due to some factors as follows:

1. Low Water Activity in Milk Powder, which significantly reduces water activity. This inhibits microbial growth and chemical reactions like hydrolysis, keeping proteins and fats relatively stable.
2. Protein Denaturation does not typically result in a loss of protein content but rather a change in protein structure. As long as the temperature doesn't exceed critical thresholds, the total protein content remains constant. On the other hand, the acidity value may increase due to the degradation of Casein and whey proteins, which release amino acids, some of which are acidic.
3. Fats in WMP are relatively stable due to the absence of water, which minimizes hydrolytic

Table 3. Moisture content of WMP samples (Mean $\pm$ Standard deviation for $n = 3$).

Reference	60 Day	90 Day	120 Day	150 Day
2.56 $\pm$ 0.01 ^{Aa}	2.57 $\pm$ 0.01 ^{Aa}	2.58 $\pm$ 0.01 ^{Aa}	2.72 $\pm$ 0.01 ^{Ba}	2.74 $\pm$ 0.01 ^{Ca}
2.57 $\pm$ 0.01 ^{Aa}	2.59 $\pm$ 0.01 ^{Bb}	2.57 $\pm$ 0.01 ^{Aa}	2.70 $\pm$ 0.01 ^{Cb}	2.81 $\pm$ 0.01 ^{Db}
2.56 $\pm$ 0.02 ^{Aa}	2.60 $\pm$ 0.01 ^{Bc}	2.57 $\pm$ 0.01 ^{Aa}	2.72 $\pm$ 0.01 ^{Ca}	2.73 $\pm$ 0.01 ^{Ca}
2.55 $\pm$ 0.01 ^{Aa}	2.57 $\pm$ 0.01 ^{Ba}	2.58 $\pm$ 0.01 ^{Ba}	2.71 $\pm$ 0.01 ^{Ca}	2.81 $\pm$ 0.02 ^{Db}
2.55 $\pm$ 0.01 ^{Aa}	2.57 $\pm$ 0.01 ^{Ba}	2.58 $\pm$ 0.01 ^{Ba}	2.72 $\pm$ 0.01 ^{Cb}	2.79 $\pm$ 0.01 ^{Dc}
2.56 $\pm$ 0.01 ^{Aa}	2.60 $\pm$ 0.01 ^{Bc}	2.58 $\pm$ 0.01 ^{Ca}	2.70 $\pm$ 0.01 ^{Db}	2.81 $\pm$ 0.01 ^{Eb}
2.56 $\pm$ 0.01 ^{Aa}	2.59 $\pm$ 0.01 ^{Bb}	2.57 $\pm$ 0.01 ^{Aa}	2.70 $\pm$ 0.01 ^{Cb}	2.79 $\pm$ 0.01 ^{Dc}
2.57 $\pm$ 0.02 ^{Aa}	2.59 $\pm$ 0.01 ^{Bb}	2.56 $\pm$ 0.01 ^{Ab}	2.72 $\pm$ 0.01 ^{Cb}	2.81 $\pm$ 0.01 ^{Db}
2.57 $\pm$ 0.01 ^{Aa}	2.58 $\pm$ 0.01 ^{Ba}	2.58 $\pm$ 0.01 ^{Aa}	2.72 $\pm$ 0.01 ^{Bb}	2.81 $\pm$ 0.02 ^{Cc}

^{ABCDE} Different capital letters in the same row refer to significant differences within storage times

$P \leq 0.05$.

^{abcd} Different small letters in the same column refer to significant differences within the samples

$P \leq 0.05$.

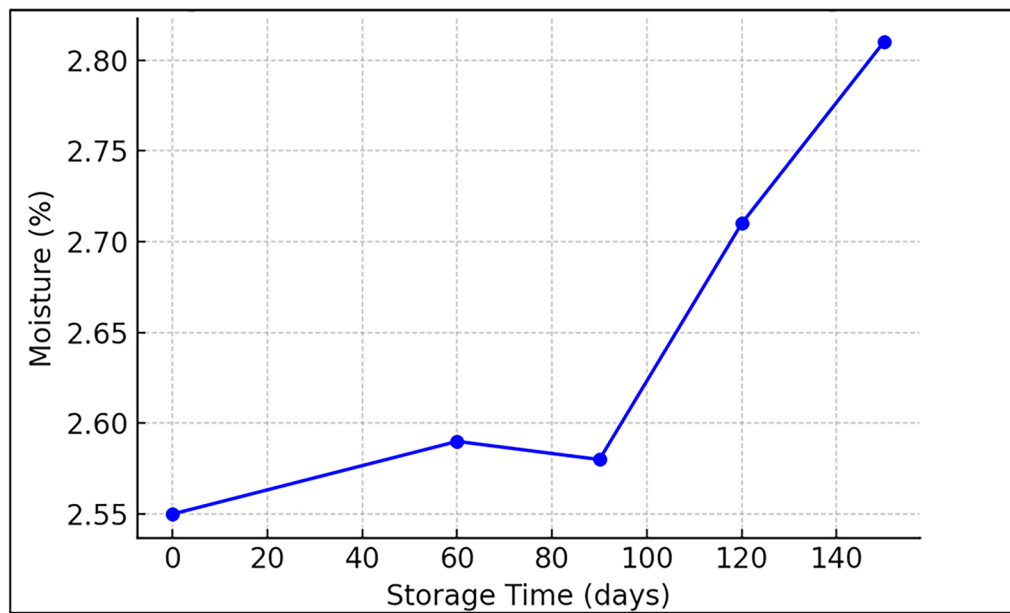


Fig. 1. Change in moisture content over storage time.

rancidity. However, oxidative rancidity could occur if the powder is exposed to oxygen and light (Zembyla, 2019). Lipid Oxidation in the milk powder can produce acidic byproducts which increase the acidity value.

- While the Maillard reaction (between proteins and sugars) can occur during storage at high temperatures, it primarily affects flavor, color, and functionality rather than the actual protein content (Liu *et al.*, 2022). A non-enzymatic browning process between proteins and lactose could contribute to increased acidity.

These results agree with Phosanam *et al.* (2021) who identified that the majority of variations in powder properties are caused by changes in free moisture

content as a result of changes in temperature and humidity.

Despite the high temperatures and long storage durations, WMP's moisture content increased significantly. This increase in the moisture content of WMP, especially under high temperatures and long storage times, is unusual and could be due to improper sealing or exposure to humid conditions during storage. Instead of Certain bacteria or microbes present in the milk could produce metabolic water as they break down milk constituents, especially under warm conditions. This might create an apparent increase in moisture as well If the milk was stored in a container with fluctuating temperatures, condensation might form and mix with the milk, increasing its moisture content. These results agreed with Vasavada

Table 4. Titrable acidity of WMP samples (Mean $\pm$ Standard deviation for $n = 3$).

Reference	60 Day	90 Day	120 Day	150 Day
13.80 $\pm$ 0.01 ^{Aa}	13.80 $\pm$ 0.01 ^{Aa}	14.20 $\pm$ 0.01 ^{Ba}	14.38 $\pm$ 0.01 ^{Ca}	14.80 $\pm$ 0.01 ^{Da}
13.80 $\pm$ 0.01 ^{Aa}	14.00 $\pm$ 0.01 ^{Bb}	14.40 $\pm$ 0.01 ^{Cb}	14.40 $\pm$ 0.01 ^{Cb}	15.20 $\pm$ 0.02 ^{Eb}
13.80 $\pm$ 0.01 ^{Aa}	14.00 $\pm$ 0.01 ^{Bb}	14.20 $\pm$ 0.01 ^{Ca}	14.40 $\pm$ 0.01 ^{Db}	14.80 $\pm$ 0.01 ^{Ea}
13.80 $\pm$ 0.02 ^{Aa}	13.80 $\pm$ 0.01 ^{Aa}	14.20 $\pm$ 0.01 ^{Ba}	14.38 $\pm$ 0.01 ^{Ca}	15.00 $\pm$ 0.01 ^{Dc}
13.78 $\pm$ 0.01 ^{Aa}	13.80 $\pm$ 0.02 ^{Ba}	14.40 $\pm$ 0.01 ^{Cb}	14.36 $\pm$ 0.01 ^{Dc}	15.20 $\pm$ 0.01 ^{Eb}
13.78 $\pm$ 0.01 ^{Aa}	13.80 $\pm$ 0.01 ^{Ba}	14.40 $\pm$ 0.01 ^{Cb}	14.38 $\pm$ 0.01 ^{Da}	14.80 $\pm$ 0.01 ^{Ea}
13.72 $\pm$ 0.01 ^{Ab}	14.00 $\pm$ 0.01 ^{Bb}	14.20 $\pm$ 0.01 ^{Ca}	14.40 $\pm$ 0.01 ^{Db}	14.80 $\pm$ 0.01 ^{Ea}
13.60 $\pm$ 0.01 ^{Ab}	14.00 $\pm$ 0.01 ^{Bb}	14.20 $\pm$ 0.01 ^{Ca}	14.40 $\pm$ 0.01 ^{Db}	14.80 $\pm$ 0.01 ^{Ea}
13.80 $\pm$ 0.01 ^{Aa}	14.20 $\pm$ 0.01 ^{Cc}	14.40 $\pm$ 0.01 ^{Cb}	14.40 $\pm$ 0.01 ^{Cb}	14.80 $\pm$ 0.01 ^{Ea}

^{ABCDE} Different capital letters in the same row refer to significant differences between storage times

P $\leq$ 0.001.

^{abcd} Different small letters in the same column refer to significant differences between the samples P $\leq$ 0.001.

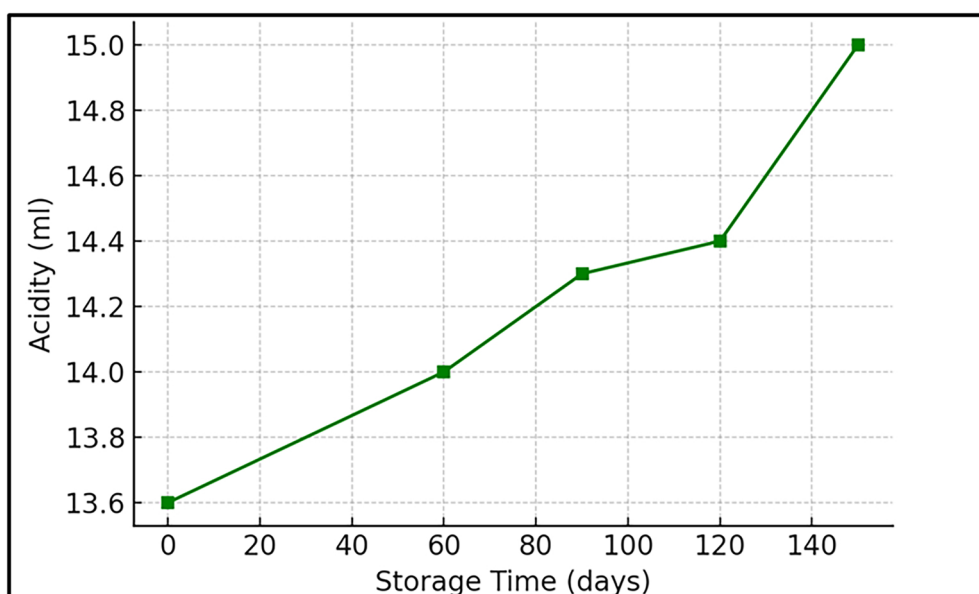


Fig. 2. Change in titrable acidity over storage time.

(1993), Tamime (2009), and Yalaw *et al.* (2024). The increase in TVC over time from the first reading (a reference to 150 days) indicates the beginning of deterioration of the dried milk substance with the increase in storage period. This is probably due to the growth of mesophilic aerobic bacteria due to non-optimal storage conditions which affects moisture value at the level of substance micro-environment. One of the most important variables influencing the quality and stability of powder milk products is their storage conditions. WMP quality during storage depends on by the processing and drying techniques of milk (Oliver, Jayarao, & Almeida, 2005). Water activity is a stronger predictor of food stability, safety, and other qualities than water content (Wason, Verma, & Subbiah, 2021). The storage stability of WMP was influenced by two

factors temperature, and storage duration treatments (Davis *et al.*, 2018).

This may explain why such a tendency to rise in TVC in WMP is controlled by moisture kinetics and water activity as this value is affected by temperature fluctuation (Paswan, Mishra, & Park, 2020). Taking into account that the IQS of shelf life for WMP should be stored in a cool and dry environment at a temperature less than 27 °C and relative humidity less than 65%.

Furthermore, WMP must be stored in a light, oxygen, and moisture-proof container, and meeting these requirements can increase storage life by up to 6–9 months. In conjunction with the tight dehydration process of fluid milk, the moisture of the milk is reduced, which inhibits the growth of microorganisms

Table 5. Total viable count results (TVC) of WMP samples (Mean $\pm$ Standard deviation for $n = 3$).

Data expressed as colony forming unit per gram (CFU \ g).

Reference	60 Day	90 Day	120 Day	150 Day
10×10^1	11×10^1	17×10^1	18×10^1	20×10^1
9×10^1	11×10^1	16×10^1	15×10^1	20×10^1
10×10^1	11×10^1	17×10^1	15×10^1	22×10^1
9×10^1	10×10^1	15×10^1	16×10^1	17×10^1
9×10^1	12×10^1	16×10^1	19×10^1	23×10^1
7×10^1	9×10^1	17×10^1	18×10^1	19×10^1
7×10^1	12×10^1	16×10^1	21×10^1	19×10^1
6×10^1	10×10^1	10×10^1	17×10^1	20×10^1
9×10^1	11×10^1	17×10^1	17×10^1	21×10^1
8.44 ± 1.42^A	10.78 ± 1.03^B	15.67 ± 2.2^C	17.33 ± 1.82^C	20.11 ± 1.83^D

^{ABCD} Different letters refer to significant differences between groups ($P \leq 0.05$),
LSD = 2.75.

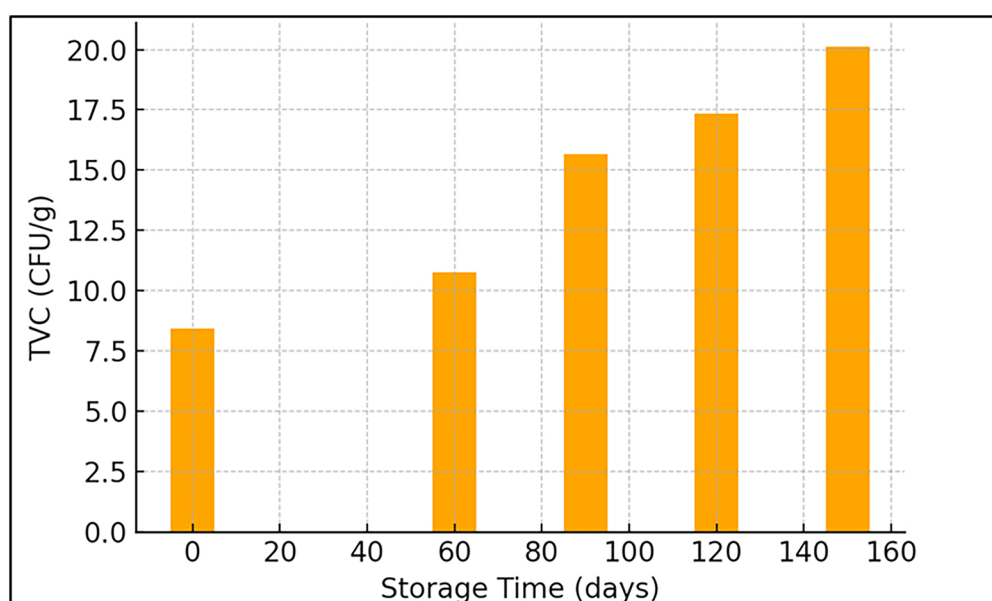


Fig. 3. Total viable count (TVC) over storage time.

and slows down the undesirable physical and chemical changes in the products (Pal *et al.*, 2016).

So such elevation in TVC indicates a primary decline in microbiological quality over time, which may affect shelf life and food safety. According to international standards (such as ISO 4833-1), TVC above 10^4 CFU/g is considered an indicator of unacceptable microbial load in dairy products. In this study, all values were within 10^1 CFU/g, indicating acceptable quality up to 150 days. However, an upward trend warrants strict monitoring.

5. Conclusion

1. Effect of storage conditions: The moisture percentage increases significantly with the increase in the storage time, as after 120 days and 150 days, the moisture increased by 6% and 9%,

respectively, compared to the reference. These increases are not random, but rather reflect a real change linked to time factors.

2. Differences between days: Long storage time exceeding 120 and 150 days showed a higher variation, which may be reflected in the chemical components of the dried milk, which in turn leads to a deterioration in quality.
3. Microbial profile tests revealed that long-term storage at high temperatures somewhat drove the deterioration of the material's quality by allowing aerobic bacteria to grow due to suboptimal conditions.

From the preceding, a high-temperature degree has a direct effect on the quality and biochemical characteristics of whole milk powder in terms of moisture content, acidity, and TVC tests. This effect increases with the length of storage time.

6. Recommendations

Monitoring storage conditions (such as humidity and temperature) to guarantee long-term storage and keep quality. Based on the results of current experiments, long-term storage negatively affects the quality of WMP. Moreover, the WMP must be processed under controlled conditions and packaged in airtight, moisture-resistant materials. This protects the WMP from environmental factors like humidity, oxygen, light, and microorganisms. Further preserving the quality of fat and protein content. Besides it uses primarily high-quality raw materials that are devoid of any evidence of corruption. However, when appropriate storage conditions are unavailable, it should take preventative measures to ensure food safety.

Conflict of interest

The Authors declare that there is no conflict of interest.

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