World Journal of Pharmaceutical Science and Research
www.wjpsronline.com
Research Article
ISSN: 2583-6579
SJIF Impact Factor: 5.111
Year - 2025
Volume: 4; Issue: 3
Page: 366-370

A COMPARATIVE STUDY OF LACTOSE AND CASEIN CONCENTRATIONS IN DIVERSE MILK MATRICES – A CASE STUDY IN PINEVILLE, LOUISIANA

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Article Received: 29 April 2025 | | ***Article Revised: 19 May 2025*** | | ***Article Accepted: 10 June 2025***

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DOI: https://doi.org/10.5281/zenodo.15672301

How to cite this Article: Oyeyemi A. O., Jaycee W., Eva V. and Asaolu M. F. (2025) A COMPARATIVE STUDY OF LACTOSE AND CASEIN CONCENTRATIONS IN DIVERSE MILK MATRICES – A CASE STUDY IN PINEVILLE, LOUISIANA. World Journal of Pharmaceutical Science and Research, 4(3), 366-370. https://doi.org/10.5281/zenodo.15672301

ABSTRACT

This study investigated and compared the presence and percentage yield of lactose and casein in seven different milk types: oat, almond, evaporated, skimmed, organic 2% fat, powdered, and goat milk. Lactose was isolated through acid precipitation, centrifugation, and crystallization, while casein was obtained via acid precipitation and centrifugation. Our findings revealed that evaporated milk exhibited the highest lactose content (21.30% yield), whereas plant-based milks (oat and almond) contained no detectable lactose. Goat milk demonstrated the highest casein yield (14.22%), while almond milk showed the lowest (0.27%). These results highlight the significant variations in carbohydrate and protein composition across different milk types, providing valuable insights for individuals with dietary restrictions or specific nutritional needs.

KEYWORDS: Goat milk, carbohydrate, protein, dietary restrictions.

INTRODUCTION

Milk is a nutrient-rich fluid, serving as a primary source of sustenance for mammals and a significant component of the human diet. Its complex composition includes essential vitamins, minerals, proteins, carbohydrates, and lipids, with the proportions varying considerably depending on the species and processing methods (Walstra et al., 1999). Among the key components are lactose, the primary carbohydrate in mammalian milk, and casein, a major group of milk proteins. Lactose, a disaccharide composed of glucose and galactose, is synthesized in the mammary glands of mammals (Jenness, 1980). Its digestion requires the enzyme lactase. Lactose intolerance, a common condition resulting from lactase deficiency, necessitates dietary awareness of lactose content in various food sources (EFSA, 2010).

Caseins are a family of phosphoproteins that constitute the primary protein fraction in milk (Fox & McSweeney, 1998). They are nutritionally complete, providing all essential amino acids. The precipitation of casein occurs when the pH of milk is lowered to its isoelectric point (around 4.6), causing the protein to become insoluble and coagulate (Walstra et al., 1999). This principle is utilized in cheese production and the isolation of casein in laboratory settings.

The increasing popularity of plant-based milk alternatives (PBMAs) derived from sources like almonds, oats, soy, and rice has broadened the spectrum of milk choices available to consumers. These alternatives are inherently lactose-free as lactose is exclusive to mammalian milk (Vanga & Raghavan, 2018). Understanding the compositional differences, particularly in lactose and casein content, between dairy and plant-based milks is crucial for informed dietary choices. This study aimed to simultaneously analyze and compare the percentage yields of both lactose and casein across a range of commonly consumed milk types.

METHODS AND MATERIALS

The materials used in this study were: seven 150 mL beakers, a pipette, seven centrifuge tubes, stirring rod, 10% acetic acid, distilled water, seven petri dishes, a balanced scale, gauze, a water bath, a thermometer, a hot plate, an ice bath, a centrifuge, and seven different milk samples. The milk samples included: oat milk, powdered milk, goat milk, skimmed milk, 2% organic milk, almond milk, and evaporated milk.

Lactose Isolation Procedure:

1. Milk Preparation: 100 mL of each liquid milk sample was used. For powdered milk, 6.98 g of powder was reconstituted with 80 mL of water to a final volume of 100 mL.
2. Acid Precipitation: Each milk sample was heated to approximately 40°C on a hot plate. 5 mL of 10% acetic acid was added to each sample while stirring until the pH reached approximately 4.6, indicated by protein coagulation .
3. Centrifugation and Supernatant Collection: 35 mL of each acidified milk solution was transferred to a centrifuge tube and centrifuged at 5000 RPM for 10 minutes. The supernatant, containing the lactose, was carefully decanted into a clean beaker, leaving the casein pellet behind. A filtering cloth was used to ensure complete separation.
4. Evaporation and Crystallization: The supernatant in each beaker was heated in a water bath on a hot plate to gently evaporate the liquid and concentrate the lactose (Nickerson, 1974). Immediately after, the concentrated solution was placed in an ice bath to induce lactose crystallization.
5. Lactose Collection and Drying: Once crystals formed, the solution was centrifuged again at 5000 RPM for 10 minutes. The remaining liquid was removed, and the collected lactose crystals were transferred to a pre-weighed petri dish to dry completely.
6. Weight Measurement and Percentage Yield Calculation: The dried lactose crystals in each petri dish were weighed using a balance scale. The percentage yield of lactose was calculated using the following formula:

   Percentage Yield=Initial Volume of Milk (mL)×Density of Milk (assumed to be 1 g/mL)Weight of Dried Lactose (g)×100

Casein Isolation Procedure

1. Milk Preparation and Acid Precipitation: This followed the same steps as the lactose isolation procedure (steps 1 and 2).
2. Centrifugation and Supernatant Removal: The acidified milk solutions were centrifuged at 5000 RPM for 10 minutes. The supernatant, now containing lactose and other soluble components, was carefully decanted, leaving the casein pellet at the bottom of the tube.

3. Washing: Distilled water was added to the casein pellet, and the mixture was resuspended and centrifuged again at 5000 RPM for 10 minutes to wash away residual acetic acid. The water was then decanted.
4. Ethanol Wash and Drying: The casein pellet was washed with ethanol (Hipp et al., 1967). The casein was then collected and allowed to air dry completely in a pre-weighed beaker.
5. Weight Measurement and Percentage Yield Calculation: The weight of the dried casein was measured using a balance scale. The percentage yield of casein was calculated using the following formula:

Percentage Yield=Initial Volume of Milk (mL)×Density of Milk (assumed to be 1 g/mL)Weight of Dried Casein (g)×100

RESULTS

Lactose Isolation

The observations during lactose crystallization varied across the milk types. Evaporated milk yielded a significant amount of large, yellow, and thick lactose crystals. Powdered and goat milk produced noticeable clumps of lactose. Skimmed and 2% organic fat milk resulted in very little visible lactose. Notably, no lactose crystals were observed in the oat and almond milk samples. The calculated percentage yields of lactose are presented below:

- Goat Milk: 1.30%
- Powdered Milk: 2.04%
- Evaporated Milk: 21.30%
- Skimmed Milk: 0.43%
- Oat Milk: 0%
- Almond Milk: 0%
- 2% Organic Fat Milk: 0.29%

Casein Isolation

The weight of the isolated casein and the corresponding percentage yields for each milk type are presented in Table 1. A Biuret test was performed on the isolated casein, with a purple tone indicating higher protein quality and a blue tone indicating lower protein quality (Gornall et al., 1949).

Table 1: Casein Weight and Percentage Yield in Different Milk Types.

Milk Type	Casein Weight (g)	% of Casein
Powder Milk	1.60	4.56
Skimmed Milk	0.29	0.79
2% Organic Milk	2.01	5.42
Almond Milk	0.09	0.27
Goat Milk	5.39	14.22
Oat Milk	0.59	1.73
Evaporated Milk	2.10	5.37

DISCUSSION

The results of this study provide a comparative overview of lactose and casein content across various milk types. The significantly high lactose yield in evaporated milk (21.30%) suggests a concentrated presence of this carbohydrate compared to other dairy-based milks tested. Powdered milk (2.04%) and goat milk (1.30%) also exhibited measurable lactose content, albeit substantially lower than evaporated milk. Skimmed and 2% organic fat milk showed the lowest lactose yields among the dairy samples (0.43% and 0.29%, respectively). As expected, the plant-based alternatives, oat and almond milk, showed a complete absence of lactose, reinforcing the understanding that lactose is unique to

mammalian milk. These findings are crucial for individuals managing lactose intolerance (Savaiano, 2014) or monitoring their carbohydrate intake.

Regarding casein content, goat milk demonstrated the highest percentage yield (14.22%), indicating a higher protein concentration compared to the other milk types analyzed. Organic 2% fat milk and evaporated milk showed comparable casein yields (5.42% and 5.37%, respectively), followed by powdered milk (4.56%). Skimmed milk and oat milk exhibited lower casein yields (0.79% and 1.73%, respectively), while almond milk had the lowest casein content (0.27%). The Biuret test indicated that animal-derived milks exhibited higher protein quality compared to plant-based milks, which aligns with existing research on protein quality . The presence of casein, even in lower quantities, in plant-based milks suggests the presence of other plant-based proteins that precipitate under acidic conditions, although they are structurally and compositionally different from mammalian casein (Boye et al., 2010).

The observed differences in lactose and casein yields can be attributed to variations in the natural composition of different animal milks and the processing methods involved in producing milk alternatives. For instance, the evaporation process concentrates the solids, including lactose, in evaporated milk. The absence of lactose in plant-based milks is a fundamental distinction.

One limitation encountered during the lactose isolation was the difficulty in completely recovering the crystallized lactose from the test tubes without some loss of material, potentially affecting the accuracy of the yield measurements. Future studies could explore alternative methods for lactose crystal collection to minimize loss.

CONCLUSION

This comparative analysis successfully quantified and compared the lactose and casein content in a variety of milk types. Evaporated milk was found to be the richest source of lactose among the tested samples, while plant-based milks (oat and almond) contained no lactose. Goat milk exhibited the highest casein content, with animal-derived milks showing higher protein quality. These findings provide valuable information for individuals with lactose intolerance, those seeking high-protein milk sources, and consumers interested in the nutritional profiles of different milk options. Further research could investigate the protein composition of plant-based milk precipitates and explore more efficient methods for isolating and purifying lactose and casein from milk.

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