

## Article

# Optimal Storage Temperature for Maintaining the Solubility of Micellar Casein Powder

Chong Chen <sup>1,†</sup>, Yun Chen <sup>2,3,†</sup>, Kerong Wang <sup>1</sup>, Yang Song <sup>1</sup>, Shengbo Yu <sup>2,3</sup>, Xuhui Fan <sup>1</sup>, Shuang Wang <sup>1</sup>, Pengjie Wang <sup>1</sup>, Weibo Zhang <sup>1,4,\*</sup> and Zhishen Mu <sup>2,3,\*</sup>

<sup>1</sup> Department of Nutrition and Health, China Agricultural University, Beijing 100193, China; chenchong409@cau.edu.cn (C.C.); 15534892026@163.com (K.W.); sy20243313941@cau.edu.cn (Y.S.); 15385662159@163.com (X.F.); wangshuang@cau.edu.cn (S.W.); wpj1019@cau.edu.cn (P.W.)

<sup>2</sup> National Enterprise Technology Center, Inner Mongolia Mengniu Dairy (Group) Co., Ltd., Hohhot 011500, China; chenyun@mengniu.cn (Y.C.); yushengbo@mengniu.cn (S.Y.)

<sup>3</sup> Global R&D Innovation Center, Inner Mongolia Mengniu Dairy (Group) Co., Ltd., Hohhot 011500, China

<sup>4</sup> Department of Food Science and Technology, Faculty of Science, National University of Singapore, Singapore 117542, Singapore

\* Correspondence: wbzhang@nus.edu.sg (W.Z.); muzhishen@mengniu.cn (Z.M.)

† These authors contributed equally to this work.

## Abstract

Maintaining the solubility of micellar casein (MC) powder during storage is a major practical challenge. This study investigated the effects of storage temperature (−20 to 37 °C) on solubility and structure of MC powder. Results showed that solubility of MC powder was well preserved at 4 °C and −20 °C over 30 d, whereas higher storage temperatures led to a marked decline. Correspondingly, particle size and stability of rehydrated solution from powders stored at lower temperatures remained unchanged but increased significantly at elevated temperatures, alongside visible precipitation. Structural analysis indicated that surface cross-linking and reduced porosity occurred during storage, resulting in decreased solubility, which were effectively suppressed at 4 °C and −20 °C. These findings demonstrate that refrigerated storage at 4 °C is sufficient to maintain the solubility of MC powder, with no clear additional advantage observed at −20 °C under the tested conditions. This work provides practical guidance for optimizing MC powder storage.

**Keywords:** micellar casein powder; storage temperature; solubility

## 1. Introduction

Micellar casein (MC) powder is produced from milk through membrane filtration and drying; its composition and physicochemical properties closely resemble those of natural casein micelles [1]. As a dairy protein ingredient, this native micellar structure makes it suitable for applications in cheese, yogurt, and protein-fortified beverages, where it imparts enhanced viscosity, texture, water binding capacity, and stability to food systems [2,3]. Furthermore, MC powder can serve as a dietary source of essential amino acids, such as leucine, isoleucine, and valine [3]. Compared with whey protein, which is rapidly digested [4], MC is characterized by slow digestibility, resulting in a more moderate and prolonged elevation of plasma amino acid levels post-ingestion [4,5]. This sustained aminoacidemia enables MC to support muscle protein synthesis over an extended period [6].

Academic Editor: Weicai Zeng

Received: 5 January 2026

Revised: 12 February 2026

Accepted: 15 February 2026

Published: 18 February 2026

**Copyright:** © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

Consequently, MC powder serves as a novel functional protein ingredient for improving both the quality and nutritional performance of food products.

Rehydration in an aqueous medium is essential for MC powder to exert its functional properties [7,8]. However, the poor solubility of MC powder limits its practical application, particularly in food systems [9,10]. To address this issue, various strategies have been developed. For instance, injecting gas (e.g., CO<sub>2</sub> or N<sub>2</sub>) into the casein micelle concentrate prior to drying can effectively improve the solubility and dispersibility of the MC powder by modifying its chemical composition and powder structure (e.g., increasing porosity, reducing bulk density) [11,12]. Additionally, partial removal of calcium ions via electro-dialysis enhances both the solubility of the MC powder, and the stability of the reconstituted solution, with the extent of improvement positively correlated with the electro-dialysis treatment time [1]. The drying method also plays a critical role [13]. MC powder produced by freeze spray drying exhibits significantly higher solubility than that from freeze drying or spray drying, attributable to higher calcium ion release and higher porosity [14]. For already dried MC powder, ultrasound treatment has been shown to enhance solubility without altering the native micellar structure or composition [15]. However, there remains a lack of strategies that can improve the rehydration of MC powder without altering its structure and composition or requiring specialized equipment for the end-user [16].

It has been shown that freshly prepared MC powder exhibits excellent solubility [17,18]. However, even when the initial solubility of MC powder is enhanced through various strategies, a gradual decline during storage is commonly observed [19,20]. This implies that maintaining the high solubility of MC powder essentially depends on preventing its deterioration during storage. The decline in solubility of MC powder may be attributed to the Maillard reaction, the formation of a surface network via non-covalent bonds, and the migration of lipids from the bulk to the surface [21,22]. Although the precise mechanisms remain partly contradictory, it is evident that interactions within MC powder change during storage [16]. Therefore, inhibiting these changes in interaction could be an effective approach to preserving the high solubility of MC powder.

The storage temperature is recognized as a critical extrinsic factor that profoundly influences the solubility of MC powder during storage [19]. Higher storage temperatures accelerate solubility loss by promoting the lipid migration to the powder surface, increasing the resistance of the surface layer, thereby hindering the release of casein from micelles [18,23]. Furthermore, the observed catch-up effect across a temperature gradient indicates that MC powder follows a consistent aging evolution curve, with lower temperatures significantly decelerating this process [18]. However, existing studies have predominantly focused on temperatures within the 4–60 °C range. It remains unclear whether lowering the storage temperature below conventional refrigeration levels provides any additional protective benefit for solubility. Clarifying this point is essential for optimizing the storage conditions and maintaining the quality of MC powder.

This study aimed to elucidate the influence of the storage temperature on the solubility of MC powder. Beyond measuring the solubility, the stability and variations in casein micelle size of the hydrated casein micelles solutions were also evaluated, which are crucial for its functional performance in applications. The results of this study offer insights for optimizing the storage conditions of MC powder.

## 2. Materials and Methods

### 2.1. Materials

Micellar casein concentrate (total solids 19.4%, casein purity 92.6%) was kindly provided by Mengniu Dairy (Group) Co., Ltd. (Hohhot, China).

## 2.2. Sample Preparation

The micellar casein concentrate was pre-frozen at  $-80\text{ }^{\circ}\text{C}$  for 24 h. Then, the sample was lyophilized for 48 h using a freeze-dryer (LGJ-10, Beijing, China) to obtain MC powder. The resulting powder had a moisture content of  $1.26 \pm 0.09\%$ , comprising bound water ( $83.43 \pm 0.08\%$ ), immobilized water ( $16.39 \pm 0.23\%$ ), and free water ( $0.18 \pm 0.16\%$ ). It was first vacuum-sealed in a PA/PE bag and then placed inside a sealed EVOH high-barrier vacuum bag. This double-bagged sample was stored in a desiccator to prevent moisture absorption. The desiccators with MC powders were stored at  $-20$ ,  $4$ ,  $25$  and  $37\text{ }^{\circ}\text{C}$  for 30 d, respectively.

## 2.3. Solubility Measurement of MC Powder

Solubility was defined as the percentage of casein remaining in suspension after centrifugation. The solubility measurement was carried out according to the reported method with some modifications [1]. Specifically, MC powders stored under different temperatures were dispersed in deionized water at room temperature to a final concentration of 2% (w/v) under continuous stirring at 550 rpm. Samples were collected at predetermined time intervals (0.5–8 h) and centrifuged ( $3000\times g$ , 10 min) to determine the solubility using the following equation:

$$\text{Solubility (\%)} = (m - m_s)/m \times 100\%$$

Here,  $m$  is the mass of the total MC powder, and  $m_s$  is the mass of the casein sediment.

## 2.4. Particle Size Measurement of Casein Micelle in MC Solutions

The particle size of casein micelle in MC solutions was determined using a Nano-ZS3600 Zetasizer instrument (Malvern, UK) [24]. A 2% (w/v) of MC solution was continuously stirred and sampled at specified intervals for size measurement. Before the measurement, each sample was diluted 100-fold with distilled water and transferred into a cuvette. Measurements were performed at a backscatter detection angle of  $173^{\circ}$ , with the refractive indices set at 1.45 for casein and 1.33 for the dispersant. The Z-average hydrodynamic diameter was obtained from the correlation function using the cumulant analysis model.

## 2.5. Stability Measurement of MC Solutions

Turbiscan LAB (Formulation, Toulouse, France) was used to assess the stability of the dispersed MC solutions based on multiple light scattering [25]. After being stirred for 6 h, about 20 mL of each MC solution was transferred into a cylindrical test tube and scanned every 10 min for 18 h. The variation in the backscattered light curve over time was recorded to determine the stability. The visual changes in the appearance of the MC solution were also photographed and recorded.

## 2.6. Microstructure Observation of Casein Micelle in MC Solutions

Scanning electron microscopy (SEM) was used to observe the microstructure of casein micelles in rehydrated MC powders. Powders stored for 1 d and 30 d were reconstituted as described in Section 2.3. The resulting casein solutions were fixed with glutaraldehyde and dried for observation, according to the method described by Ren et al. [14].

## 2.7. FTIR Spectra of MC Powder

FTIR spectroscopic analysis of the MC powder was performed using a INVENIO S spectrometer (Bruker, Germany) to assess the changes in intermolecular interactions induced by storage temperature. The measurement was carried out in ATR mode with a spectral range of  $4000\text{--}400\text{ cm}^{-1}$ .

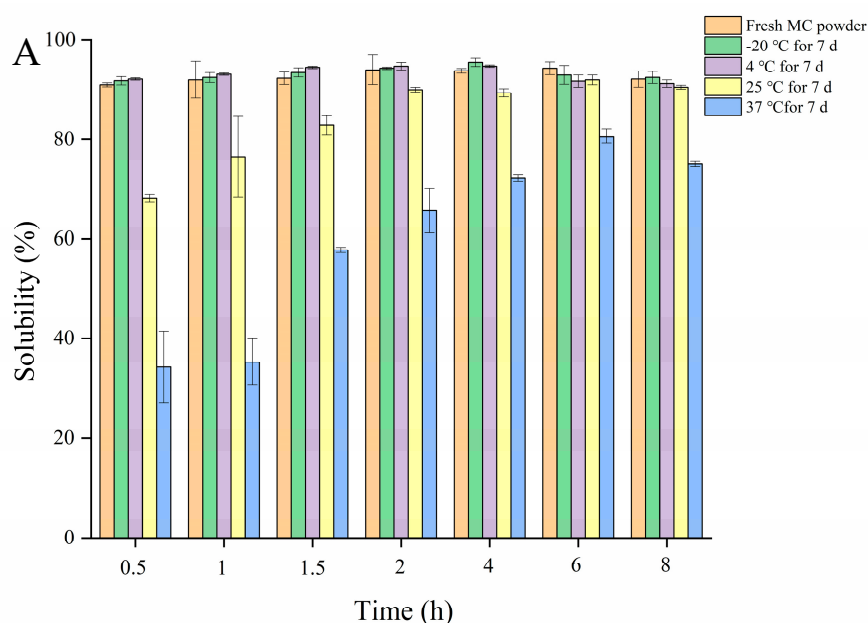
## 2.8. Statistical Analysis

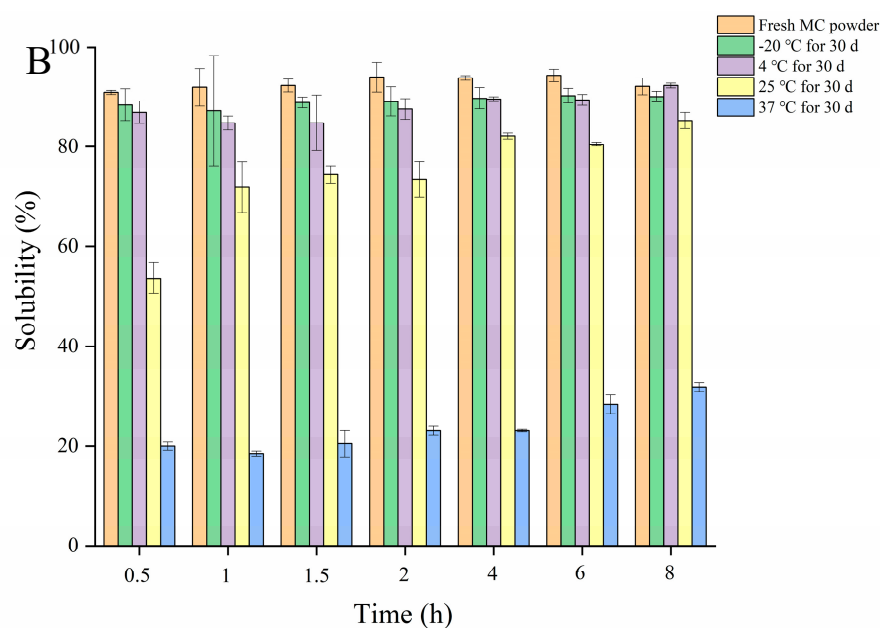
Experiments were carried out in triplicate, and the results were expressed as the mean  $\pm$  standard deviation. Statistical significance was assessed using one-way ANOVA with Duncan's test. Differences were considered significant at  $p < 0.05$ .

## 3. Results and Discussion

### 3.1. Solubility of MC Powder

The solubility of MC powder stored at different temperatures is shown in Figure 1. The freshly prepared MC powder exhibited good solubility, with over 80% of casein dissolving, which is consistent with the previously reported results [17]. During storage, the solubility of the MC powder stored at 37 °C declined sharply by day 7 and dropped to approximately 20% by day 30. Extending the hydration time did not enhance the solubility further. The MC powder stored at 25 °C showed a slower decrease in solubility than that at 37 °C; however, its solubility was significantly lower than that of powders stored at 4 °C and −20 °C. These results indicate that lower storage temperatures effectively decelerate the solubility loss, which is similar to the previous findings [18]. Notably, the MC powders stored at 4 °C and −20 °C demonstrated comparable solubility, suggesting that reducing the temperature below 4 °C provides no additional protection against solubility decline. Therefore, storing MC powder at refrigerated temperature is sufficient to maintain its high solubility.

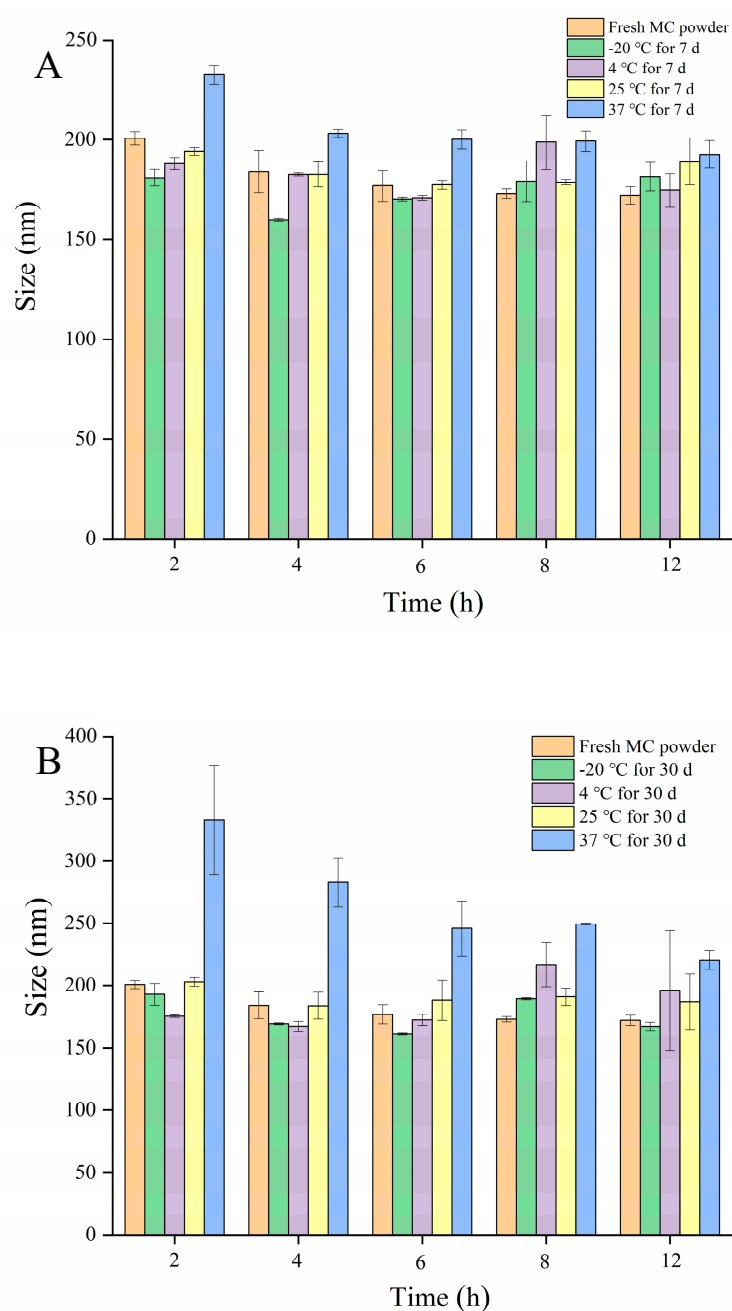




**Figure 1.** The solubility of MC powders stored at different temperatures for 7 d (A) and 30 d (B).

### 3.2. Particle Size of Casein Micelle in MC Solutions

Figure 2 shows the variation in the size of the casein micelles during the dissolution of MC powders. The particle size of casein micelles in freshly prepared MC solutions was approximately 180 nm, close to that of native casein micelles [26]. No significant difference in the particle size of casein micelle was observed between the solutions prepared from MC powders stored at 4 °C and −20 °C. Furthermore, the particle size for these low-temperature samples remained stable throughout storage, aligning with their high solubility. A slight increase in particle size was detected for the powder stored at 25 °C. In contrast, after storage at 37 °C, the casein micelles showed a pronounced increase in size. This can be attributed to the formation of a cross-linked network on the MC powder surface during high-temperature storage, which hinders casein release during dissolution, thereby reducing the solubility and increasing the particle size [23]. Given that the casein micelle size is closely related to its functional properties (e.g., gelation property, emulsifying capacity) [27], the increase in casein size during storage is expected to significantly impair functionality. Consequently, low-temperature storage is beneficial for preserving the functional characteristics of MC powder.

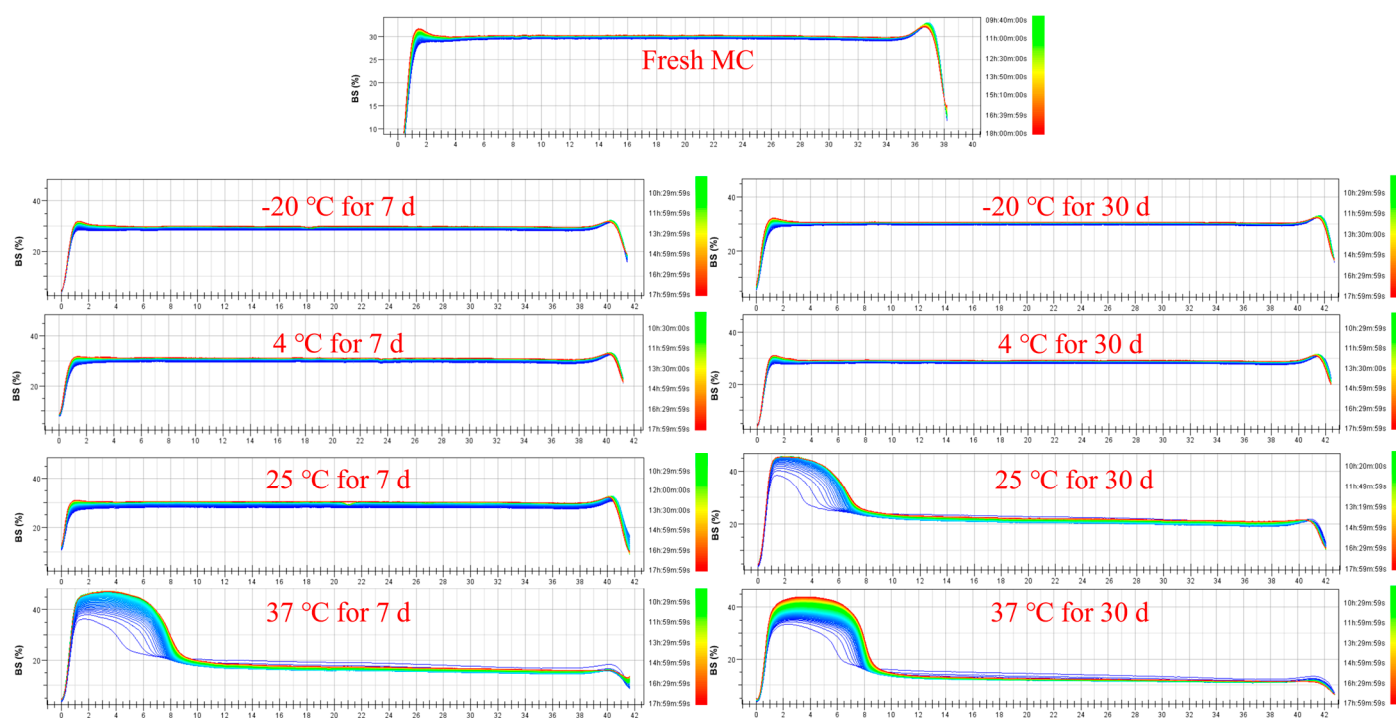


**Figure 2.** The particle size of casein micelles in solutions prepared from MC powders stored at different temperatures for 7 d (A) and 30 d (B).

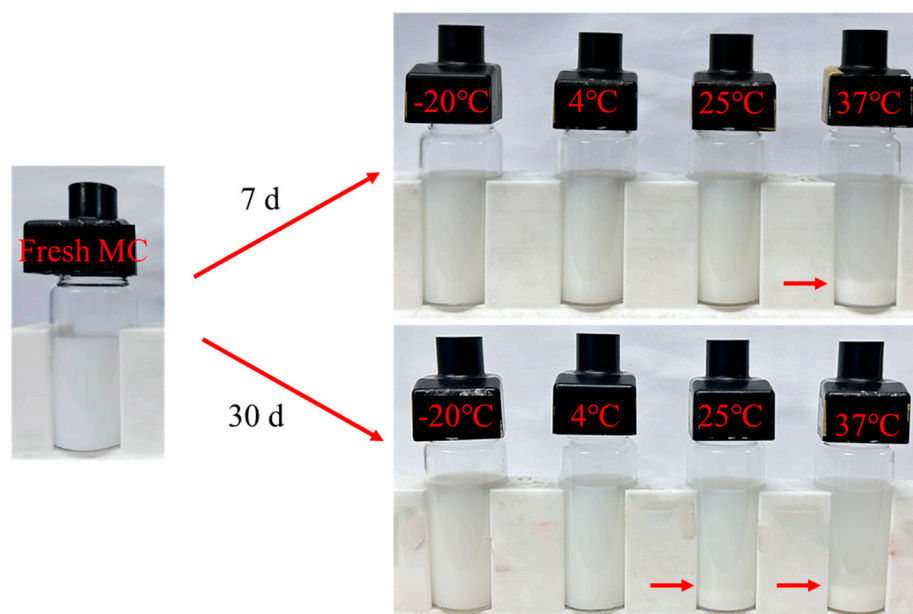
### 3.3. Stability of MC Solutions

The stability of the MC solution is a key quality parameter affecting the application of MC powder in dairy processing and functional foods [28]. Therefore, the stability of the solutions prepared from MC powders stored at different temperatures was analyzed and presented in Figure 3. The backscattering (BS) profiles reflect particle migration (creaming or sedimentation) and flocculation phenomena [29]. The backscattering profile of the freshly prepared MC solution remained largely unchanged over 18 h, indicating a homogeneous and stable state, as stable dispersions typically exhibit flat BS curves over time [25]. Similarly, solutions from MC powders stored at 4 °C and −20 °C for 7 and 30 d showed backscattering curves comparable to the fresh sample, with no notable variation

over time. For the MC powder stored at 25 °C for 7 d, the backscattering curve of MC solution showed little change, but a significant increase in backscattering intensity at the bottom, accompanied by a slight decrease in the upper region was observed for the powder stored for 30 d. The increase in backscattering at the bottom indicates sedimentation (Figure 4), as the backscattering intensity is directly proportional to the particle concentration [1,30]. For the MC powder stored at 37 °C, visible sedimentation of casein occurred in the MC solutions after just 7 d (Figure 4), and the sedimentation rate of the casein accelerated with storage time up to 30 d, as a sharp rise in BS profiles at the bottom and a corresponding depletion in the top were observed. These results are consistent with the maintained small particle size and high solubility, confirming that low-temperature storage effectively preserves the colloidal stability of reconstituted casein micelles.



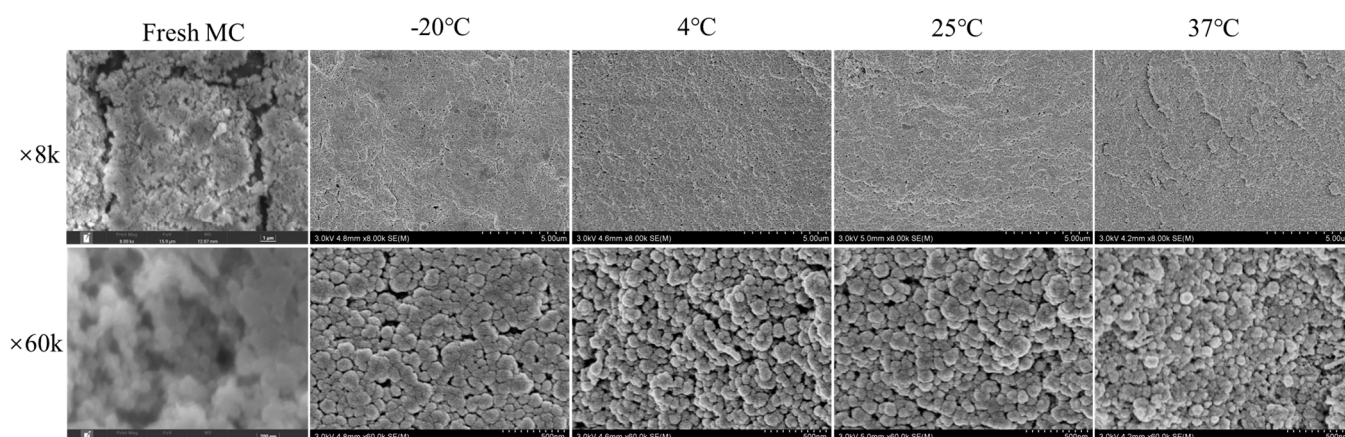
**Figure 3.** The stability of solutions prepared from MC powders stored at different temperatures.



**Figure 4.** The appearance of solutions prepared from MC powders stored at different temperatures.

### 3.4. Microstructure Changes of MC Powder During Storage

Figure 5 shows the microstructure of MC powders after 1 h of rehydration. The freshly prepared MC powder exhibited a porous structure, with spherical clusters of casein particles dispersed within pores of various sizes. These casein particles were interconnected through direct contact or via surface-extended segments, forming a coarse network, consistent with previously reported results for spray-dried MC powder [31]. Compared to the fresh sample, MC powders stored at 4 °C and −20 °C for 30 d displayed a relatively denser surface structure and reduced inter-particle porosity, which was similar to the previous study [9]. However, the overall network structure was largely retained. As the storage temperature increased, the spherical casein particles appeared tightly packed with minimal interstitial space, and the characteristic open gel network was lost. The higher storage temperature induced a decrease in porosity and an increase in the compactness of MC powder surface structure. Moreover, the spherical casein particles in MC powder stored at 37 °C were slightly smaller than those in other groups, indicating lower hydration and swelling, which is detrimental to powder dissolution [31]. These differences in the microstructure of MC powders suggest that surface cross-linking occurs during storage and is highly correlated with the storage temperature. Higher storage temperature promotes the formation of a dense surface film that hinders water penetration and casein release, thereby reducing the solubility [23,32]. Therefore, lowering the storage temperature effectively suppresses surface cross-linking, helping to maintain the solubility of MC powder.

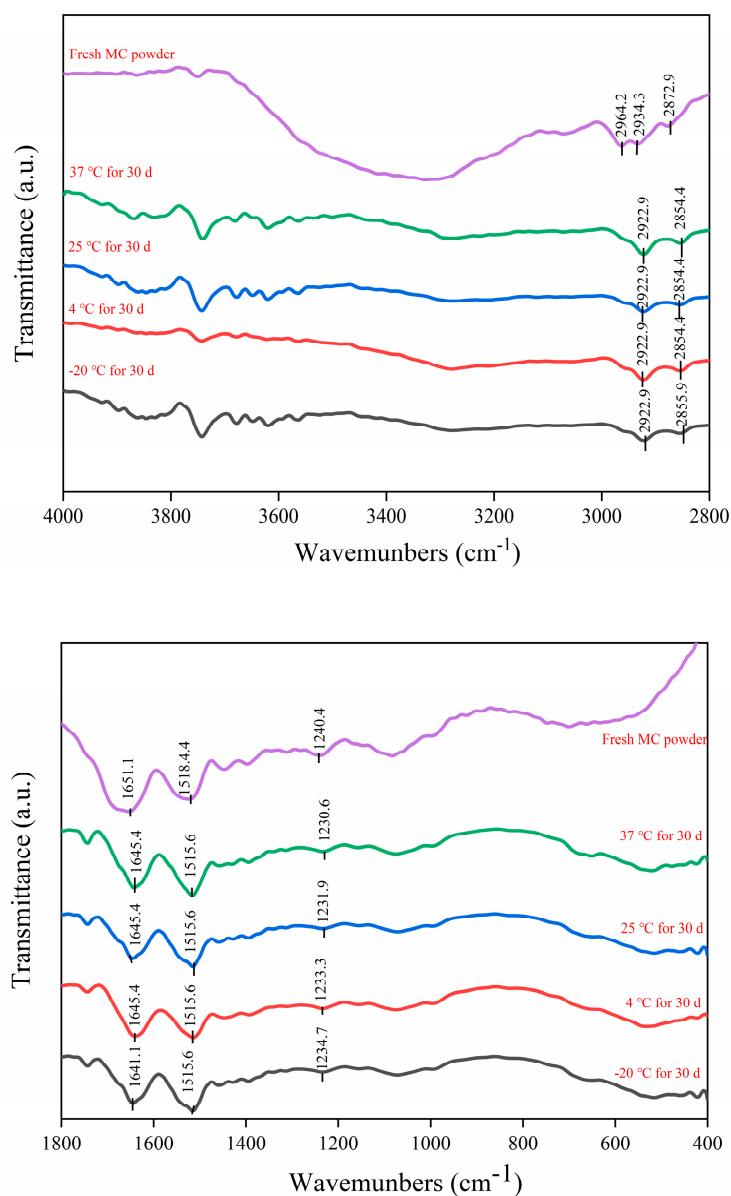


**Figure 5.** The microstructure of MC powder after 1 h of rehydration.

### 3.5. FTIR Spectra Changes of MC Powder During Storage

The FTIR spectra of the MC powders are presented in Figure 6. The peaks of freshly prepared MC powder at 2964  $\text{cm}^{-1}$  and 2934  $\text{cm}^{-1}$ , assigned to the stretching of C-H and bending of  $-\text{CH}_3$  groups, were weakened or shifted to a lower wavenumber after storage, suggesting the possible exposure of hydrophobic groups. Furthermore, the characteristic amide bands of freshly prepared MC powder shifted to lower wavenumbers after storing at different temperatures, indicating conformational changes in the peptide backbone of the casein. These conformational changes possibly indicated an increase in  $\beta$ -sheet-like structures, consistent with protein aggregation during storage (Figure 5) [22]. Notably, the FTIR spectra showed minimal variation across MC powders stored at different temperatures, implying that similar types of structural alteration occurred in all samples. This observation appears inconsistent with the results of the solubility. This discrepancy arises because FTIR is primarily a qualitative technique, and relying on amide band shifts to interpret solubility differences is insufficient [17]. Although FTIR cannot precisely quantify the extent of molecular interactions, the spectral changes support that low-

temperature storage effectively suppresses cross-linking, helping to maintain solubility of MC powder.



**Figure 6.** The FTIR spectra of the MC powders.

#### 4. Conclusions

This study investigated the effects of storage temperature on the solubility of MC powder. The freshly prepared MC powder exhibited good solubility; this property declined during storage, with the rate of decline accelerating at higher temperatures. Lower storage temperatures (4 °C) effectively decelerated the deterioration of solubility, and a further reduction in storage temperature below 4 °C did not provide additional protective benefits against solubility loss under the tested conditions. The storage temperature also significantly impacted the properties of the reconstituted solution. Powder stored at low temperatures maintained stable micelle size and formed stable dispersions, whereas powder stored at elevated temperatures yielded solutions with significantly larger micelles and visible protein precipitation. SEM and FTIR analyses revealed that surface crosslinking occurred on MC powder during storage; lowering the storage temperature helps to

promote casein release from powder, thereby enhancing the solubility. These findings elucidate the impact of storage temperature on both the solubility and structural properties of MC powder, providing a theoretical basis for optimizing its storage conditions. Given the relatively short storage period examined in this study, future research will focus on longer-term storage to further evaluate its effects on the solubility and functional properties (e.g., gelation property, emulsifying capacity) of MC powder.

**Author Contributions:** Conceptualization, C.C., W.Z., and Z.M.; methodology, C.C., Y.C., K.W., Y.S., S.Y., X.F., and S.W.; investigation, C.C., Y.C., K.W., Y.S., S.Y., X.F., S.W., and P.W.; resources, S.Y. and P.W.; data curation, C.C., Y.C., and K.W.; writing—original draft preparation, C.C. and Y.C.; writing—review and editing, W.Z. and Z.M.; project administration, W.Z. and Z.M.; funding acquisition, P.W. and Z.M. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the Key projects of National Natural Science Foundation of China under Grant Number 32130081, the National Natural Science Foundation under Grant Number 32402011, and the Postdoctoral Fellowship Program of CPSF under Grant Number GZC20241936.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

**Conflicts of Interest:** Authors Y.C., S.Y., and Z.M. were employed by the company Inner Mongolia Mengniu Dairy (Group) Co., Ltd. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

1. Wang, K.; Chen, Y.; Fan, X.; Yu, S.; Song, Y.; Wang, S.; Zhang, W.; Wang, P.; Wang, S.; Zhu, Y.; et al. Enhanced Rehydration of Micellar Casein Powder: Effects of Electrodialysis Treatment. *Foods* **2025**, *14*, 4171. <https://doi.org/10.3390/foods14244171>.
2. Wu, Z.X.; Ren, R.J.; Li, A.R.; Zhang, Y.; Zhang, X.Y.; Wang, P.J.; Wang, C.Y.; Zhang, W.B.; Zhang, J.; Luo, J.; et al. Tailoring the properties of casein-based composite gels via regulation of the  $\kappa/\iota$  ratio for  $\kappa$ 2-carrageenan. *LWT* **2025**, *238*, 118818.
3. Hammam, A.R.A.; Martínez-Monteagudo, S.I.; Metzger, L.E. Progress in micellar casein concentrate: Production and applications. *Compr. Rev. Food Sci. Food Saf.* **2021**, *20*, 4426–4449.
4. Gorissen, S.H.M.; Trommelen, J.; Kouw, I.W.K.; Holwerda, A.M.; Pennings, B.; Pennings, B.; Wall, B.T.; Churchward-Venne, T.A.; Horstman, A.M.H.; Koopman, R.; et al. Protein Type, Protein Dose, and Age Modulate Dietary Protein Digestion and Phenylalanine Absorption Kinetics and Plasma Phenylalanine Availability in Humans. *J. Nutr.* **2020**, *150*, 2041–2050.
5. Trommelen, J.; Weijzen, M.E.G.; van Kranenburg, J.; Ganzevles, R.A.; Beelen, M.; Verdijk, L.B.; van Loon, L.J.C. Casein Protein Processing Strongly Modulates Post-Prandial Plasma Amino Acid Responses In Vivo in Humans. *Nutrients* **2020**, *12*, 2299. <https://doi.org/10.3390/nu12082299>.
6. Agarwal, S.; Beausire, R.L.W.; Patel, S.; Patel, H. Innovative Uses of Milk Protein Concentrates in Product Development. *J. Food Sci.* **2015**, *80*, A23–A29.
7. Wu, S.; Fitzpatrick, J.; Cronin, K.; Miao, S. Effects of calcium chelation on the neutralization of milk protein isolate and casein micelle reassembling. *Food Chem.* **2020**, *332*, 127440.
8. Dudi, K.; Khatkar, S.K. Development of highly soluble and functional buffalo milk protein concentrate 60 by modifying ionic environment and characterisation thereof. *Int. J. Dairy Technol.* **2023**, *76*, 226–239.
9. Burgain, J.; Scher, J.; Petit, J.; Francius, G.; Gaiani, C. Links between particle surface hardening and rehydration impairment during micellar casein powder storage. *Food Hydrocoll.* **2016**, *61*, 277–285.

10. Zhong, Q.; Luo, S.; Fitzpatrick, J.; Jiang, L.; Guo, Z.; Lin, J.; Zheng, H.; Zeng, H.; Wu, C.; Zheng, S.; et al. Effect of calcium chelation on the physio-chemical characteristics and rehydration behavior of spray-dried casein-rich powder. *J. Food Eng.* **2025**, *400*, 112658.
11. Marella, C.; Salunke, P.; Biswas, A.C.; Kommineni, A.; Metzger, L.E. Manufacture of modified milk protein concentrate utilizing injection of carbon dioxide. *J. Dairy Sci.* **2015**, *98*, 3577–3589.
12. McSweeney, D.J.; Maidannyk, V.; O'Mahony, J.A.; McCarthy, N.A. Influence of nitrogen gas injection and agglomeration during spray drying on the physical and bulk handling properties of milk protein concentrate powders. *J. Food Eng.* **2021**, *293*, 110399.
13. Conceição, D.G.; Reis, L.C.C.; da Silva Virgens, E.; de Jesus, J.C.; Bauer, L.C.; Chaves, M.A.; Bonomo, R.C.F.; Santos, L.S.; Ferrão, S.P.B. Thermal, structural and spectroscopic properties of powder sheep milk obtained by different drying methods. *Int. Dairy J.* **2024**, *150*, 105845.
14. Ren, J.; Liao, M.; Ma, L.; Chen, F.; Liao, X.; Hu, X.; Miao, S.; Fitzpatrick, J.; Ji, J. Effect of spray freeze drying on the structural modification and rehydration characteristics of micellar casein powders. *Innov. Food Sci. Emerg. Technol.* **2022**, *80*, 103093.
15. Wu, S.; Li, G.; Xue, Y.; Ashokkumar, M.; Zhao, H.; Liu, D.; Zhou, P.; Sun, Y.; Hemar, Y. Solubilisation of micellar casein powders by high-power ultrasound. *Ultrason. Sonochemistry* **2020**, *67*, 105131.
16. McSweeney, D.J.; O'Mahony, J.A.; McCarthy, N.A. Strategies to enhance the rehydration performance of micellar casein-dominant dairy powders. *Int. Dairy J.* **2021**, *122*, 105116.
17. Haque, E.; Bhandari, B.R.; Gidley, M.J.; Deeth, H.C.; Møller, S.M.; Whittaker, A.K. Protein Conformational Modifications and Kinetics of Water-Protein Interactions in Milk Protein Concentrate Powder upon Aging: Effect on Solubility. *J. Agric. Food Chem.* **2010**, *58*, 7748–7755.
18. Nasser, S.; Moreau, A.; Jeantet, R.; Hédoux, A.; Delaplace, G. Influence of storage conditions on the functional properties of micellar casein powder. *Food Bioprod. Process.* **2017**, *106*, 181–192.
19. Cao, J.; Wang, G.; Wu, S.; Zhang, W.; Liu, C.; Li, H.; Li, Y.; Zhang, L. Comparison of nanofiltration and evaporation technologies on the storage stability of milk protein concentrates. *Dairy Sci. Technol.* **2016**, *96*, 107–121.
20. Liu, D.; Zhang, J.; Yang, T.; Liu, X.; Hemar, Y.; Regenstein, J.M.; Zhou, P. Effects of skim milk pre-acidification and retentate pH-restoration on spray-drying performance, physico-chemical and functional properties of milk protein concentrates. *Food Chem.* **2019**, *272*, 539–548.
21. Le, T.T.; Bhandari, B.; Deeth, H.C. Chemical and Physical Changes in Milk Protein Concentrate (MPC80) Powder during Storage. *J. Agric. Food Chem.* **2011**, *59*, 5465–5473.
22. Nasser, S.; Hédoux, A.; Giuliani, A.; Le Floch-Fouéré, C.; Santé-Lhoutellier, V.; de Waele, I.; Delaplace, G. Investigation of secondary structure evolution of micellar casein powder upon aging by FTIR and SRCD: Consequences on solubility. *J. Sci. Food Agric.* **2018**, *98*, 2243–2250.
23. Nasser, S.; Jeantet, R.; De-Sa-Peixoto, P.; Ronse, G.; Nuns, N.; Pourpoint, F.; Burgain, J.; Gaiani, C.; Hédoux, A.; Delaplace, G. Microstructure evolution of micellar casein powder upon ageing: Consequences on rehydration dynamics. *J. Food Eng.* **2017**, *206*, 57–66.
24. Chen, C.; Zhang, W.; Wang, P.; Zhang, Y.; Zhu, Y.; Li, Y.; Wang, R.; Ren, F. Thermo-responsive composite nanoparticles based on hydroxybutyl chitosan oligosaccharide: Fabrication, stimulus release and cancer therapy. *Int. J. Biol. Macromol.* **2024**, *276*, 133842.
25. Chen, C.; Zhang, W.; Zhang, Y.; Li, Y.; Zhang, F.; Wang, J.; Wang, X.; Zhang, X.; Ren, F.; Wang, P. Emulsion stability of hydroxybutyl chitosan as emulsifier at low pH: Effects of the degree of substitutions of hydroxybutyl groups. *Int. J. Biol. Macromol.* **2024**, *258*, 128868.
26. Wang, J.; Zhang, W.; Guo, Q.; Li, W.; Hong, Y.; Gong, J.; Zhang, F.; Chen, C. Improved textural properties of transglutaminase treated milk acid gel: Influence of citric acid. *J. Agric. Food Res.* **2024**, *18*, 101270.
27. Zhang, Y.; Ren, F.; Wang, P.; Liang, Q.; Peng, Y.; Song, L.; Wen, P. The influence of yak casein micelle size on rennet-induced coagulation properties. *J. Sci. Food Agric.* **2021**, *101*, 327–333.
28. Yuan, J.; Liu, D.; Peng, X.; Jiang, Y.; Gao, Y.; Liu, X.; Regenstein, J.M.; Zhou, P. The heat stability of caprine and bovine micellar casein dispersions. *Int. Dairy J.* **2022**, *131*, 105373.
29. Luo, Y.; Song, Y.; Su, L.; Zhou, Y.; Chen, C.; Du, Z.; Sun, Y. Impacts of heat and noncovalent bonding on interfacial property and structure of goat milk fat globule membrane proteins. *npj Sci. Food* **2025**, *10*, 21.
30. Wang, P.; Chen, C.; Guo, H.; Zhang, H.; Yang, Z.; Ren, F. Casein gel particles as novel soft Pickering stabilizers: The emulsifying property and packing behaviour at the oil-water interface. *Food Hydrocoll.* **2018**, *77*, 689–698.

31. Mimouni, A.; Deeth, H.C.; Whittaker, A.K.; Gidley, M.J.; Bhandari, B.R. Investigation of the microstructure of milk protein concentrate powders during rehydration: Alterations during storage. *J. Dairy Sci.* **2010**, *93*, 463–472.
32. Ho, T.M.; Ton, T.T.; Gaiani, C.; Bhandari, B.R.; Bansal, N. Changes in surface chemical composition relating to rehydration properties of spray-dried camel milk powder during accelerated storage. *Food Chem.* **2021**, *361*, 130136.

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.