

Micellar Casein Concentrate: Unlocking New Opportunities in Dairy and Nutrition

Vaghasiya Dhyey SanjayBhai, Heena Sharma, Ashish Kumar Singh and *Gaurav Kr Deshwal

Dairy Technology Division, ICAR-National Dairy Research Institute, Karnal, Haryana

gaurav.deshwal@icar.org.in

Milk proteins are important for structural and nutritional quality of milk and milk products. Casein consists of nearly 80% of total protein content in bovine milk. The unique self-aggregation nature and adaptability of casein towards different processing conditions like acidity and temperature make them essential component in dairy industry, especially in production of cheese and fermented dairy products. With increasing consumer demand towards protein-rich foods, the dairy industry has increasingly focused on developing high-protein products. Micellar casein concentrate (MCC) has emerged as a novel ingredient, that is rich in casein and low in whey proteins. MCC is obtained by microfiltration of skim milk using a membrane of 0.1-0.2 μm pore size, in which intact casein micelles are separated in retentate and whey proteins, lactose and some soluble salts passes into the permeate (Hammam et al., 2021). The resulting retentate is highly rich in casein (around 80-90 % of total protein). Milk protein concentrate (MPC) unlike MCC has both casein and whey protein in the 80:20 ratio. MCC is mainly used in application where high heat stability is desirable, since MCC does not contain whey protein so no denaturation occurs. MCC offers superior functional properties such as emulsifying properties, heat stability and water binding ability (Hammam et al., 2022). The protein fraction is readily digested and offers necessary amino acids, enabling uses in functional and nutritional foods (Hammam et al., 2022).

Composition of micellar casein concentrate

MCC contains approximately 75-90% protein on a dry matter basis, 3% fat, 1% lactose, 8% ash and approximately 5% moisture (Figure 1). Approximately 80-90 % of total protein in MCC is casein. In MCC, the micellar structure of casein micelles is maintained, protecting calcium phosphate nanoclusters and guaranteeing their functional stability. The microfiltration process substantially reduces lactose, with concentration of <2-3% depending on processing conditions of diafiltration process. This low lactose content enhances the suitability of MCC for lactose-reduced formulations and for consumer with

lactose intolerance (Hammam et al., 2022). Minerals associated with casein micelles such as calcium and phosphorus which support structural integrity and nutritional value are preserved in MCC.

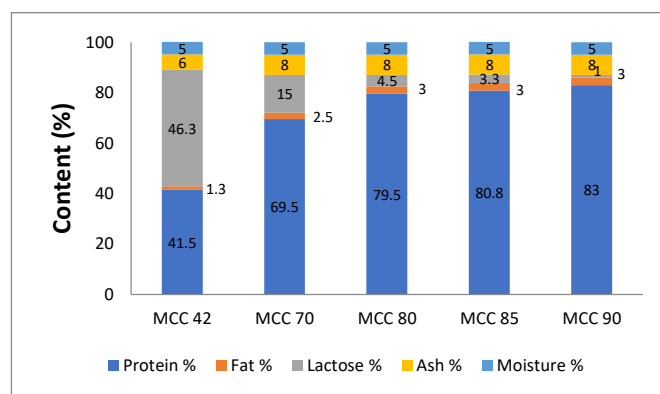


Figure 1 Composition of different types of micellar casein concentrate (MCC). MCC followed by a number indicates the protein content (%) of the micellar casein concentrate.

Production of MCC

MCC is produced from skim milk having 3.2-3.4% protein and low microbial counts ($<10^3$ CFU/mL). Fat is removed to less than 0.05 % to avoid fouling of polymeric or ceramic membranes during processing (Marella et al., 2021). To preserve the native micellar structure, pasteurization at 72-75°C for 15-20 s is preferred, thereby maintaining colloidal calcium phosphate integrity and minimizing protein denaturation (Hammam et al., 2022). Spiral-wound polymeric membranes with pore size of 0.1-0.2 μm operated at transmembrane pressure of 0.3 to 1 bar selectively retain casein micelles while allowing whey proteins, lactose and soluble minerals to permeate. The microfiltered retentate is concentrated using UF membranes having molecular weight cut-off of 10-30 kDa to increase protein content to 8-12 % (Hammam et al., 2022). The lactose (<2%) and salt content of the concentrate is reduced using diafiltration. Diafiltration is carried out by mixing water with retentate in different ratios. Diafiltration maintains flux rates to more than 80% of initial flux throughout extended runs (Marella et al., 2021).

The retentate is concentrated by using falling film evaporator. At protein concentration exceeding 12-14%, viscosity increases sharply above 200 mPa.s at 20°C creating difficulties in heat transfer and pumping of concentrate (Hammam et al., 2022). The concentrate obtained is spray dried at an inlet air temperature of 180-200°C and outlet temperature of 80-90 °C.

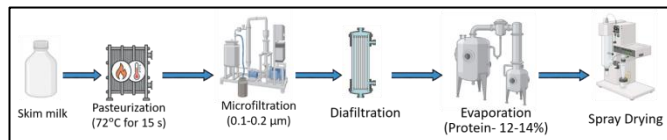


Figure 2 Process flow diagram representing the production of micellar casein concentrate from skim milk

Properties of micellar casein concentrate

The characteristics of MCC are significantly affected by the methods used for its separation throughout processing. Conventional isolation techniques such as isoelectric precipitation and rennet coagulation usually damage the native micellar structure which leads to altered functional properties. In contrast, microfiltration offers mild, physical separation that retains casein in their native micellar structure. The functional characteristics of MCC vary depending on protein concentration, mineral composition, pH and processing conditions.

MCC shows higher heat stability compared to other dairy protein ingredients, largely due to its higher casein concentration and intact structure of casein micelle. Under UHT processing at 143°C for 3 s and retort sterilization at 121°C for 15-20 min, liquid MCC having 8% protein showed higher heat stability than rehydrated MPC powders. MPC powders exhibit poorer heat stability due to presence of both casein and whey proteins, which rapidly denature under heat. The higher heat stability of MCC enables its use in shelf-stable dairy beverages. MCC having intact casein micelles have poor solubility as the major techno-commercial hurdle. The lower solubility and rehydration properties of MCC powders are major limitation for its use in food and beverages formulation. MCC powders, exhibits slower dissolution compared to low heat milk powders, due to slow release of casein micelles into the solution from powder particles. Rehydration times of 30-40 min at 35-60oC under high shear are often required to achieve full hydration (Crowley et al., 2016). Treatments such as incorporation of calcium chelators like trisodium citrate or increased ionic strength with addition of NaCl can improve solubility of MCC.

A special property associated with concentrated liquid MCC is cold gelation. In contrast to

traditional casein products, MCC forms a strong gel at low temperature (around 20°C), which is pourable and pumpable at room temperature and can be disrupted at temperatures about 50°C. At higher concentration, casein micelles are densely aggregated, causing the elongated protein chains to obstruct each other. This obstruction retards their mobility and when sufficient thermal energy is available to overcome such obstacles, the proteins aggregate and create a gel (Carter et al., 2021). The rehydrated MCC is characterized by sweet aromatic, cooked, milky and distinct corn chip or tortilla like flavour. Flavour evaluation shows that it is completely dependent on protein content. With increasing protein content from skimmed milk powder, MPC to MCC, sweet aromatic intensity declines while cardboard notes increase due to loss of volatile compounds during diafiltration. MCC has reduced risk of sulphur off flavours in high heat processed drinks advantage due to lower whey protein content (Carter et al., 2021)

Applications of MCC

MCC has been used in various dairy and food applications due to its nutritional value, bland flavour and functional properties. Due to its high heat stability, MCC can also be used as ingredients in sterilized dairy beverages and in cheese manufacturing. MCC could be used for preparing high protein and low lactose beverages. MCC acts as a stable delivery system for calcium and phosphorus that can remain stable at high temperature. The bland flavour of MCC provides a mouthfeel similar to low fat milk, thus can be used for low-fat milk beverages (Hammam et al., 2021). MCC has also been reported to improve rheological properties of Greek yoghurt. MCC improves texture and firmness of yoghurt as well as accelerates acidification rate due to higher non-protein nitrogen (Bong & Moraru, 2014). The adjustment of casein to fat ratio of milk for cheese preparation using MCC lead to improved curd structure and cheese yield (Guinee et al., 2009). MCC has been successfully used to manufacture Cheddar and Mozzarella cheese with higher yield, better curd matrix and higher proteolysis. The recombined milk prepared from MCC and cream offers flexibility in protein-to-fat ratios for specialized cheese formulation.

Table 1. Applications of micellar casein concentrate in dairy and food industry

Product(s)	Effect on product
Pasta products: macaroni, pasta, imitation pasta	Nutritional, texture, freeze-thaw stability, microwavable

Confectionary	Chewy texture, water binding, emulsifier, foaming, high-temperature stability, improves flavour, whipping properties
Meat products	Emulsifier, water binding improves consistency, releases meat proteins for gel formation and water binding, pre-emulsion, gelation, yield
Special dietary preparations	Dieting patients, bodybuilders, athletics, astronauts, nutritional fortification, low lactose foods, bioactive peptides, casein hydrolysates
Convenience foods	Whitening agents, dairy flavour, flavour enhancer, emulsifier, stabilizer, viscosity controller, freeze-thaw stability, egg yolk replacement, lipid replacement

Conclusion

MCC has become a versatile dairy product with a variety of uses in cheese, yogurt and beverages. For developing high protein formulations with better texture and processing efficiency, its functional qualities such as high heat stability, enhanced solubility and unique cold gelation are crucial. Future works are needed to utilize MCC in making more dairy products and study the functionality of these products.

References

- Carter, B. G., Cheng, N., Kapoor, R., Meletharayil, G. H., & Drake, M. A. (2021). Invited review: Microfiltration-derived casein and whey proteins from milk. *Journal of Dairy Science*, 104(3), 2465–2479.
- Guinee, T. P., O'Kennedy, B. T., Kelly, P. M., & Mounsey, J. (2009). Micellar casein powders with different levels of calcium and cheeses prepared therefrom (World Intellectual Property Organization Patent No. WO2009150183A1). <https://patents.google.com/patent/WO2009150183A1/en>
- Hammam, A. R. A., Beckman, S. L., & Metzger, L. E. (2022). Production and storage stability of concentrated micellar casein. *Journal of Dairy Science*, 105(2), 1084–1098.
- Hammam, A. R. A., Martínez-Monteagudo, S. I., & Metzger, L. E. (2021). Progress in micellar casein concentrate: Production and applications. *Comprehensive Reviews in Food Science and Food Safety*, 20(5), 4426–4449.
- Marella, C., Sunkesula, V., Hammam, A. R. A., Kommineni, A., & Metzger, L. E. (2021). Optimization of Spiral-Wound Microfiltration Process Parameters for the Production of Micellar Casein Concentrate. *Membranes*, 11(9).
- Micellar Casein Concentrate | ThinkUSAdairy by the U.S. Dairy Export Council. (n.d.). Retrieved May 30, 2026, from <https://www.thinkusadairy.org/products/milk-proteins/milk-protein-categories/micellar-casein-concentrate>
- Sauer, A., & Moraru, C. I. (2012). Heat stability of micellar casein concentrates as affected by temperature and pH. *Journal of Dairy Science*, 95(11), 6339–6350.