Microphotography of Raw and Processed Milk

Beverly Rubik

A Pilot Study

Raw milk is a colloid, in which fat globules of various sizes are dispersed within a watery phase of dissolved proteins, carbohydrates, vitamins, electrolytes and minerals, along with low levels of probiotic bacteria such as lactobacillus. The purpose of this pilot study is to examine whole milk—raw and processed—to look for any differences in its colloidal structure that can be seen using an optical microscope. In particular, we looked for differences between unpasteurized raw whole milk compared to whole milk that is pasteurized (heated to 170 degrees F for nineteen seconds) or ultrapasteurized (heated to 280 degrees F for two seconds, using superheated metal plates and steam, and then chilled). We also looked at the effects of homogenization of milk. Milk samples were observed under the microscope over a large range of magnification and two types of illumination, bright field and dark field.

PROCEDURES AND METHODS

Five types of commercial fresh whole milk were sampled, as follows:

1. Ultrapasteurized, homogenized whole milk
2. Organic pasteurized (not ultrapasteurized), homogenized whole milk
3. Organic pasteurized (not ultrapasteurized), unhomogenized ("cream top") whole milk
4. Raw whole organic milk, brand “A”
5. Raw whole organic milk, brand “B”

The milk was purchased and sampled on the same day and kept under the same refrigeration until minutes before sampling. Because milk is a heterogeneous liquid, each milk container was gently inverted in the carton or bottle several times in a similar fashion to mix it just before sampling. Using a pipette, a small volume (50 microliters) of milk was placed on a clean glass microscope slide. A glass cover slip was placed over it to spread out the droplet. This constituted a sample slide. Sample slides were made just before observation and photography under the bright-field microscope and again just before dark-field observation, so that all samples observed were individually and similarly prepared just before microphotography.

The following magnifications were used with bright-field microphotography, in which the sample was illuminated from below with a tungsten lamp: 75x, 175x, and 350x.

The following magnifications were used with dark-field microphotography, in which the sample was edge-illuminated with a xenon lamp using a dark-field
condenser: 500x, 800x, 1200x, 2100x, and 4200x. We achieved higher magnifications than the usual limit of light microscopy by means of digital optical enhancement. Altogether eight different magnifications, ranging from 75x to 4200x, were used to examine each milk sample.

Representative photographs were taken at least in triplicate for each power of magnification. Thus, at least twenty-four digital micro-photographs per type of milk were produced and compared, for a total of one hundred twenty photographs.

RESULTS

The one hundred twenty photographs were visually examined and qualitatively compared to examine the colloidal structure of the different types of milk at different magnifications and illumination.

Figure 1 shows raw milk at 175x under bright field, which shows a distinct colloidal structure of aggregates of the fat globules (white) amidst aqueous regions (dark). By comparison, Figure 2, which shows pasteurized unhomogenized milk also at 175x, shows much smaller aggregates of fat globules and a more uniform colloidal structure. Figure 3, which shows pasteurized, homogenized milk, and Figure 4, which is ultrapasteurized, homogenized milk, both at 175x, show no discernible colloidal structure at this magnification, as a virtually uniform gray field is seen. The horizontal scale for Figures 1 to 4 is 1.33 mm (millimeters) for the full width of each microphotograph.
FIGURE 1 Raw milk magnified 175 times
FIGURE 2 Pasteurized, unhomogenized milk, magnified 175 times

FIGURE 3 Pasteurized, homogenized milk magnified 175 times
FIGURE 4 Ultra-pasteurized, homogenized milk, magnified 175 times

Figures 5, 6, 7, and 8 show raw milk; pasteurized, unhomogenized milk; pasteurized homogenized milk; and ultrapasteurized, homogenized milk respectively. All photographs are 800x magnification.

Here, too, the raw milk shown in Figure 5 exhibits the most detailed ultrastructure, with greater variation in density of structure and material in regions throughout the photograph. Figure 6 showing pasteurized unhomogenized shows a less detailed structure at the same magnification compared to raw milk in Figure 5. A visual comparison of Figures 5 and 6 (unhomogenized milk) to Figures 7 and 8 (homogenized milk), shows how homogenization breaks down fat globules to a size that is no longer distinguishable at this power of magnification. Here the horizontal scale for these 4 figures is 0.29 mm (millimeters) for the full width of each microphotograph.
FIGURE 5 Raw milk magnified 800 times
FIGURE 6 Pasteurized, unhomogenized milk, magnified 800 times
FIGURE 7 Pasteurized, homogenized milk magnified 800 times
FIGURE 8 Ultra-pasteurized, homogenized milk, magnified 800 times

Figures 9 and 10 compare raw milk and ultrapasteurized, homogenized milk at 4200x. The horizontal scale for these 2 figures is 0.055 mm (millimeters, 55 micrometers) for the full width of each microphotograph.

The heterogeneity in size of the fat globules is seen for the raw milk, ranging in size up to 7 micrometers in diameter, with many in the range of 3 to 5 micrometers. However, the fat globules are smaller, more homogeneous in size, and indistinct in the processed milk, ranging in size only up to 2.3 microns, and with mostly smaller fat globules present.
FIGURE 9 Raw milk magnified 4200 times
There is an apparent trend seen in these examples shown and all of the photographs taken, that the most highly processed milk—ultrapasturized and homogenized—shows the least distinct colloidal structure and the most homogeneity using the optical microscope. By contrast, raw milk shows the most distinct colloidal structure under the microscope at all magnifications observed, and this was the case for both commercial brands of raw milk. The raw milk ultrastructure consisted of a variety of sizes of milk fat globules, as seen under the highest powers of magnification, and in addition, patterns of organization of these globules when viewed under lower magnifications that appeared to be fractal in nature, that is, self-similar at various powers of magnification.

**CONCLUSION**

Raw whole milk is a natural colloid which has a structure that can be seen across a range of magnifications under a light microscope. In this regard, it is like a living system that shows an organized structure seen under the microscope at the same levels of magnification that living cells show organized structure, too. Thus, raw milk appears to have an organized yet complex and heterogeneous structure, as do living organisms, that is, the property of organized heterogeneity in various domains of order.
Pasteurization as well as homogenization alters the colloidal structure of milk, rendering it a less complex and more homogeneous liquid. Such milk has lost its structural complexity.

We could not distinguish any differences between pasteurized milk and ultrapasteurized milk from the microphotographs. Moreover, the milk that was pasteurized at the lower temperature but unhomogenized looked similar to raw milk at high magnifications as the heterogeneous size of the fat globules, ranging from about 2 to 7 micrometers, were similar.

It must be said that the optical microscope has limitations and cannot distinguish particles smaller than about 0.2 micrometers. Thus, any structure about this size or smaller cannot be resolved by light microscopy.

During sample preparation, it was noted that organic whole milk that is pasteurized but unhomogenized could not be completely mixed by hand mixing or shaking. Chunks of fat similar to butter were floating at the surface of the milk or stuck to the milk container, despite gentle inversion of the milk or even vigorous shaking for minutes. Thus, it appears that pasteurization itself has permanent effects on the fat globules of whole milk, making much of the fat congeal and separate from the watery phase of the milk, much like butter.

**DISCUSSION**

A colloid is a unique state of condensed matter in which small particles are dispersed in a liquid phase such as water. Milk is a complex aqueous colloid: a micro-structured aggregate of water, fat globules, various proteins, carbohydrates, electrolytes, vitamins and minerals. This may be compared to the colloidal state of the living cell itself, composed of similar constituents, which used to be called protoplasm, the primary material inside the living cell, as shown in the amoeba in Figure 11. Moreover, raw milk and blood (see Figure 12) look remarkably similar at high magnification.
FIGURE 11 Amoeba observed under dark-field microscopy, which has a similar colloidal structure to raw milk.
FIGURE 12 Normal healthy blood magnified 4200 times.

Scientific research shows that this colloidal state is dynamic, ubiquitous and appears to be integral to life’s functions. In fact, some natural colloids, such as proteins and fat particles in water, even display life-like responses to certain stimuli. That is, aqueous colloids—sols and gels—show some typical properties of living organisms, such as sensitivity to geo-cosmic rhythms (Piccardi, 1962), including circadian rhythms of day and night and solar rhythms such as the sunspot cycle of eleven years. Colloids can also absorb energy, such as light, and self-organize into larger, more complex forms, similar to living systems (Zhao et al., 2008). Some pioneering scientists working at the frontiers of water research think that many of the mysteries of life are intimately related to properties of aqueous colloids and water interfaces with membranes, a topic that is under considerable research activity at present (Pollack et al., 2006).

In light of the apparent relationship between colloidal structure and living function, let us reflect further on the results of this study. We have observed that pasteurization, ultra-pasteurization, and homogenization impact the colloidal structure of milk, altering its organizational integrity. Heat, as is used in pasteurization, is well known to denature the quaternary structure of proteins, deactivate enzymes, destroy vitamins and kill microbes. Homogenization affects the integrity of the fat globules, rendering them smaller and more uniform, and thus, alters raw milk’s colloidal ultrastructure, too. In summary, we have observed that processed milk loses “organized heterogeneity,” a term synonymous with the living state. Thus, whereas raw milk may be considered “alive,” processed milk is seen to be “lifeless.”

REFERENCES


ACKNOWLEDGEMENT

This study was funded in part by the Weston A. Price Foundation. The author would also like to acknowledge Harry Jabs, who made helpful comments and edits of earlier drafts of this paper.

This article appeared in Wise Traditions in Food, Farming and the Healing Arts, the quarterly journal of the Weston A. Price Foundation, Summer 2012.