



Heat Stress Effects on Milk Fat Globule Size in Crossbred Cows: Preliminary Considerations

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Abstract

The size of the fat globules in milk affects creaming, churning, cheese texture and the amount of globule membrane material per unit of fat, and it is known to vary with the cow's fat output, diet and genotype. Heat stress alters all of the physiological inputs on which globule size is thought to depend, yet its effect on globule size has received little direct study, and almost none in the taurine-zebu crossbred cows that produce much of the milk in tropical and subtropical regions. This short communication does not report measurements. It sets out, from established knowledge of mammary lipid secretion and of the metabolic response to heat, the routes by which a sustained heat load could shift the globule size distribution, and it considers which direction of change each route predicts. The reasoning suggests that smaller globules are the more likely outcome where heat stress depresses fat yield, but that opposing influences exist and the net effect cannot be deduced. The note then describes the precautions that any study of the question would need, particularly in sample handling and particle sizing under hot conditions, and outlines a simple design for crossbred herds. It is offered as a starting point for that work.

Keywords: Milk fat globule, Heat stress, Crossbred dairy cattle, Milk fat, Temperature-humidity index, Laser light scattering

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1. Introduction

Milk fat is secreted as globules that range from roughly a tenth of a micrometre to more than ten micrometres in diameter, each enclosed in a membrane derived from the secretory cell (Mulder and Walstra, 1974; Lopez, 2011). The size distribution is not a fixed property of cow's milk. It differs between cows in the same herd on the same ration (Logan et al., 2014), and it has practical weight: small globules cream more slowly, carry more membrane per gram of fat and behave differently in cheese and butter making.

Heat stress is among the best-documented constraints on dairy production in warm climates. It lowers feed intake and milk yield and alters milk composition (Kadzere et al., 2002; West, 2003). Crossbreds of

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Bos taurus and *Bos indicus* are widely kept in the tropics because they combine some of the heat tolerance of zebu cattle with higher yield (Hansen, 2004). Whether and how a heat load changes the size of the fat globules in their milk is a question on which the literature offers little direct evidence. This note sets down what can be reasoned from established findings and what a first study should attend to.

2. What Is Known About the Control of Globule Size

Globules begin as small lipid droplets formed at the endoplasmic reticulum of the mammary epithelial cell. The droplets grow by fusion as they move to the apical surface, where they are enveloped in plasma membrane and released (Heid and Keenan, 2005). Final size therefore reflects the balance between the rate of triglyceride synthesis, the extent of droplet fusion and the supply of membrane to wrap the product.

Several influences on that balance have been described, and Figure 1 gathers them. The most consistent is fat output: Wiking et al. (2004) found that average globule diameter rose with the daily fat yield of the cow, which fits the idea that membrane becomes limiting when much fat is secreted. Diet matters, with cows on fresh pasture producing smaller globules than cows on a maize silage ration (Couvreur et al., 2007). Stage of lactation, genotype and the metabolic state of the animal contribute as well, and Argov-Argaman (2019) has reviewed how these factors may act through the availability of membrane phospholipid relative to triglyceride.

3. Routes by Which Heat Stress Could Act

Heat stress touches nearly every item in Figure 1. Table 1 lists four routes, the established basis of each and the direction of change it would predict. The entries in the last column are inferences and should be read as hypotheses.

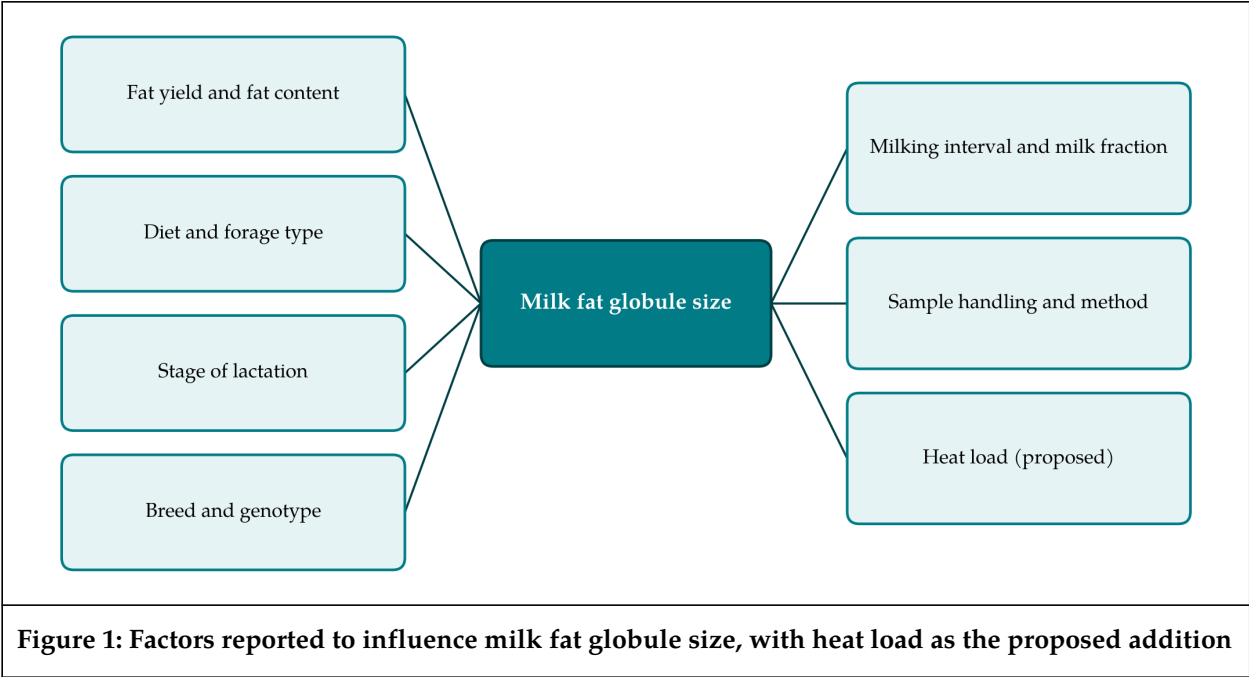


Figure 1: Factors reported to influence milk fat globule size, with heat load as the proposed addition

The first route is the most direct. If heat stress reduces the daily output of fat, as it commonly does through lower yield and sometimes lower fat content (West, 2003), the relationship reported by Wiking et al. (2004) predicts a shift towards smaller globules. The second concerns the origin of the fatty acids. A cow that eats less would ordinarily draw on body fat, sending long-chain fatty acids to the udder. Heat-stressed cows are unusual in that they do not mobilise adipose tissue to the expected degree despite their energy deficit (Baumgard and Rhoads, 2013). The mammary gland of a heat-stressed cow is thus supplied differently from that of a cow underfed in cool conditions, and the two states should not be assumed to give the same globules.

Table 1: Possible routes from heat stress to altered milk fat globule size, and the change each would predict

Route	Established basis	Predicted effect on globule size
Lower fat yield	Heat stress reduces milk and often fat yield; size rises with fat yield	Smaller globules
Altered fatty acid supply	Body fat is not mobilised as expected under heat stress	Probably smaller; uncertain
Change of diet	Intake falls and forage-to-concentrate ratio often shifts	Depends on the ration
Concentration of milk	Yield may fall more than fat synthesis in some cows	Larger globules, if fat content rises
Udder health	Hot, humid conditions favour mastitis	Unclear; possible damage to globules

Other routes pull in different directions. Rations are often reformulated for hot weather, and cows select against forage when hot, so a dietary effect is confounded with the thermal one. In an individual animal whose milk volume falls further than fat synthesis, fat content rises and larger globules might follow. The net result cannot be deduced, and it may differ between crossbreds of different zebu inheritance, since their heat tolerance, yield and milk fat content all differ from those of purebred taurine cows ([Hansen, 2004](#)).

4. Measurement Under Hot Conditions

A study in a hot environment faces a hazard that has nothing to do with the cow. Globules coalesce, cluster and lose membrane when warm milk is agitated, pumped, cooled slowly or stored, and each of these events shifts the measured distribution. Samples taken on a hot day and carried to a distant laboratory are exposed to exactly these conditions, and more so than samples from the cool-season comparison, so an artefact of handling can pass for an effect of heat stress.

Precautions follow directly. Milk should be sampled by hand or from a gently mixed bucket of the whole milking, since globule size differs between fore-milk and strippings; held at a constant moderate temperature and measured within hours; and never frozen. Laser light scattering is the usual sizing method. It requires that casein micelles be dissociated, normally with a chelating agent, so that they are not counted as small particles, and it depends on the refractive index assigned to milk fat ([Michalski et al., 2001](#)). Results should be reported as full distributions with the volume-weighted and surface-weighted mean diameters, because a single average can hide a change in the tail of large globules.

5. Outline of a First Study

A workable design for a crossbred herd would follow the same cows through a cool and a hot period, recording the temperature-humidity index in the housing alongside rectal temperature and respiration rate as evidence that the animals were in fact heat-stressed. Milk yield, fat content and globule size distribution would be measured on each sampling day, with feed intake and ration composition recorded so that dietary change can be separated from thermal load in the analysis. Stage of lactation advances between periods and must be handled by including cows calving at different times. Genotype, expressed as the proportion of zebu inheritance, is a natural factor to include. Fatty acid profiles would show whether a change in globule size accompanies a change in the origin of the fat.

6. Conclusion

Established physiology gives good reason to expect that heat stress alters milk fat globule size, and the best-supported inference is a shift towards smaller globules where fat yield falls. That inference has not

been confirmed in crossbred cows, opposing mechanisms exist, and handling artefacts are a real risk in hot conditions. Careful sampling, proper particle sizing and a within-cow seasonal design would turn these preliminary considerations into evidence.

Conflict of interest

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