DOES WELFARE OF DAIRY COWS AFFECT QUALITY OF MILK AND DAIRY PRODUCTS?

Marisanna SPERONI, Sara CARÉ

Consiglio per la Ricerca e la Sperimentazione in Agricoltura, Centro di Ricerca per le Produzioni Foraggere e Lattiero-Casearie, Sede distaccata di Cremona, Italy

Corresponding author email: marisanna.speroni@entecra.it

Abstract

The paper presents a non-systematic review about the relationship between welfare of dairy cows and quality of milk that they produce; the best demonstrated links are the effects of mastitis and oxidative stress on composition, shelf life, sensory and technological characteristics of milk and milk products. These evidences explained how specific aspects of animal welfare affected specific aspects of milk quality. Further interdisciplinary efforts should be made, in the light of the new strategy of the European Commission on animal welfare, new knowledge and emerging disciplines; welfare of dairy cows should be evaluated at farm level by a widely agreed protocol using outcome-based animal indicators; how and how much the animal welfare, measured in such way, affects the quality of milk should be studied by very large surveys and carefully designed experiments.

Keywords: *animal welfare, dairy cows, milk quality, dairy products*

INTRODUCTION

Worries about animal welfare are often associated with expectations about quality of animal products. Two of the main reasons of concern about welfare of dairy cows are that husbandry has become more and more intensive and that genetic selection for production traits could have side effects on animal reactivity. There is a widespread perception that unhappy and sick cows produce bad milk; however a direct relation between animal welfare and food quality is not easily demonstrable because ―food quality" and ―animal welfare" are, both, very complex concepts**.**

Food quality includes food security and safety, nutrition, sensory and others attributes related with product differentiation. Consumers' ability of processing information about quality is limited because some attributes of food quality can not be evaluated by visual perception or by experience. Considering the consumers' ability to distinguish it, foods traits have been classified into search, experience or credence attributes (Caswell and Mojduszka, 1996 cited by Olynk et al. 2010). An attribute is considered as a search attribute if consumers are able to identify its quality before purchase through either inspection or research; the quality of an experience attribute can be determined only after purchasing and consuming the product; a credence attribute is classified as one for which quality could not be assessed even after the product was purchased and consumed (Olynk et al. 2010). For livestock products, animal welfare is often a credence attribute; a crucial challenge for researchers is to produce data and tools allowing to transform most of food quality attributes from credence attributes to search ones.

Public awareness on animal welfare has been growing worldwide; in Europe, the concern for livestock welfare has resulted in political movement and regulations of the care of farm animal. More recently, the leading role of the market in driving development of animal friendly methods of production has received big attention and the public awareness is beginning to influence directly farm practices.

So far, one of the main obstacles on the way to a characterization of the products in relation to the animal welfare has been the difficulty of measuring it by feasible and objective methods based on scientific data. Over time, many protocols have been proposed for the assessment of welfare in

dairy farms and many resources have been spent to choose the best and give them a scientific basis. Now, there is a general agreement on the fact that very effective direct measurements (i.e., outcome-based animal welfare indicators) are available and must be used.

Recently, the European Commission adopted a new four-year strategy (2012-2015) (Commission Communication to the European Parliament, the Council and the European Economic and Social Committee, http://ec.europa.eu/food/animal/welfare/actionplan/docs/aw_strategy_19012012_en.pdf).

The new strategy aims to further improve the welfare of animals in the European Union and produce a simplification of the EU legislation on animal welfare, allowing more flexibility and less costs of compliance. A better enforcement is also expected as consequence of a more systematic approach and more transparency.

The new strategy will be based on the use of outcome-based animal welfare indicators. The EFSA Scientific Opinions on the development of welfare indicators (EFSA, 2012) will be taken into account.

Even there are growing evidences that an higher animal welfare could be economically convenient for farmers, one of the problem that must be considered is that improving animal welfare can increase cost of products; thus one question is if the people will accept higher prices for more friendly animal products.

Pala and Atakisi (2012) showed that sensory perception of different level of animal welfare by tasting yogurt was strengthened when sensory input was supported with information provided on animal welfare; they suggest that friendly animal products should be advertised and labeled clearly to increase consumer sensory acceptance and willingness.

Science on willingness to pay for animal welfare in dairy production (WTPD) is still in its infancy (Carlucci et al. 2009; Napolitano et al. 2008; Napolitano et al. 2010; Elbakidze e Nayaga, 2012); thus, experiments and surveys on WTPD don‘t give yet consistent results, being different in methods and showing differences across products. However, we can assume a higher WTPD if the animal welfare attributes will be associated with higher quality of products.

Aim of this review is to analyze the experimental evidences of a link between welfare of dairy cows and the quality of milk that they produce.

MATERIAL AND METHODS

A computerized literature research was carried out to update an existing archive of published reports about relationship between animal welfare and quality of milk and dairy products.

The keywords ―milk quality", ―yogurt" and ―cheese" were combined trough the Boolean operator ―and" with the keywords ―animal welfare" or ―animal wellbeing" on PubMed to find out scientific article published for the last five years. Additionally, some cross-references mentioned in the selected articles were checked and retained if relevant.

Then, a non-systematic review of selected number of articles has been conducted to highlight the state of the art on this topic.

RESULTS AND DISCUSSION

Many aspects of animal welfare have been demonstrated to affect the milk quality: sickness, oxidative stress, cognitive stress, nutritional stress and environmental stresses.

Sickness

The best demonstrated link of milk quality with health of cows is the effect of mastitis on composition and physical characteristics of milk and milk products (Barbano et al 1997; Barbano et al 2006).

Milk produced during mastitis is characterized by a higher somatic cell count (SCC); mastitis induces increased proteolysis, lipolysis, and free fatty acids content (Table 1).

The increased proteolysis is, partially, due to increased activity of plasmin. Since 1995, Ballou et al., through an investigation into the bulk milk of 200 farms ranked on the basis of the SCC, showed that the level of plasmin (PL) in milk is higher for farms with higher SCC. Plasmin is a protease, part of a complex protease-protease inhibitor system that exists in milk in its inactive zymogen form,

plasminogen that can be converted into active PL by plasminogen activators (Grufferty and Fox, 1988). The proteolysis induced by PL can have both positive or negative effects on the texture and the flavor of dairy products (Ismail and Nielsen, 2010) depending on the degree of hydrolysis and the type of product; proteolysis in cheese during ripening results in texture modifications, pH increase through NH_3 formation and the production of flavor compound (Fox et al., 1993); thus, a certain degree of protein‘s hydrolysis contributes to develop the consistency and flavor you want; in pasteurized or sterilized milk, excessive proteolysis is undesirable because reduce the shelf life and may lead to develop bitter off-flavors (Ma et al., 2000) due to the accumulation of small peptides.

Table 1. Demonstrated effects of mastitis on milk and dairy products

Effect on the animal physiology	**Effects on milk characteristics**	**Negative consequeces on quality of milk and dairy products**	**References**
Accumulation of leukocytes produced by the cow‘s immune system at the infection site (udder)	Increased cell somatic count; increased activity of non-plasmin proteases (somatic cell protease)	Reduction of shelf life of fluid milk due to accumulation of small peptides developing bitter and astringent off-flavors Increase in rennet coagulation time and reduction in curd firming rate.	Ma et al., 2000 Politis and Ng-Kwai-Hang 1988
Increased tight junctions permeability	Increased plasmin activity	Reduction of shelf life of fluid milk due to accumulation of small peptides developing bitter and astringent off-flavors Increase in rennet coagulation time and reduction in curd firming rate.	Ma et al., 2000; Ismail and Nielesen S.S., 2010. Politis and Ng-Kwai-Hang 1988.
	Reduced de novo synthesis in the udder. Increased leakage of blood components into the udder	Lower concentration of calcium, lactose, casein and fat Higher concentration of sodium, chlorine and serum protein	Kitchen 1981; Stelwagen, 1999; Delamaire and Guinard-Flament, 2006.
Increased susceptibility of milkfat substrate to lipase activity?	Increased lipolysis	Reduction of shelf life of milk and yogurt due to increased free fatty acids content leading to rancid off-flavors.	Ma et al., 2000; Shipe et al 1978; Fernandes et al., 2007.

The variations of the content of plasmin and plasminogen in milk are, partially, related to changes in the tight junctions (TJ) permeability; TJ are the intercellular junctions of the secretory cells of the mammary gland. In healthy udders, during lactation, the mammary epithelial TJ limits permeability and exchanges between milk and blood; when a pathogenic microorganism penetrates in the teat canal irritates and invades the mammary tissue, causing an inflammatory response with partial or complete breaking of TJ and increase of permeability of epithelium. In such conditions, *de novo* synthesis of milk components in the udder is reduced and the influx of the blood components into the milk is increased; there is an increased transfer of plasminogen from blood plasma to milk where it is activated to plasmin. The same thing happens in situations of stress and at the end of lactation.

Moreover, when the TJ become leaky, calcium, lactose, casein and fat contents are reduced in milk, while concentrations of sodium, chlorine and serum proteins increase (Kitchen 1981; Stelwagen, 1999; Delamaire and Guinard-Flament, 2006).

However, during mastitis, also a contribution of non-plasmin proteolitic activity from somatic cells, especially phagocitic leukocites (polymorfonucleocytes and macrophages) occurs. These cells contain active proteases; when milk SCC is maintained elevated (1

million cells/ml or more) their contribution becomes significative.

When SCC is high also lipolysis is high and affects negatively taste and technological properties of milk. Lipases catalyse hydrolytic release of free fatty acids from triglycerides causing a flavour defect in fluid milk described as ―rancid" (Shipe et al 1978).

Increased lipolysis in yogurt (Fernandes et al., 2007) and lower yield in cheeses (Politis and Ng-Kwai-Hang 1988) have been also reported as consequences of mastitis.

Oxidative stress

Oxidative stress is the result of an imbalance between prooxidants processes and antioxidants processes.

Tissues of animals under oxidative stress show an excessive production of free radicals; free radicals are compounds with an unbalanced electronic structure that gives them a great reactivity towards organic constituents and cellular structures; for this characteristic, free radicals are involved in a large number of redox reactions and are formed continuously, along the energy metabolism, contributing to the adaptation of an organism to the environment; however an excess of free radicals is harmful, can alter cellular structures and reduce the effectiveness of the immune system cells.

Diseases, bacterial, viral infections and any situation of stress, such as improper handling of animals, extreme cold and heat stress, excessive dietary levels, unbalanced diets stimulate the production of free radicals.

In cows, oxidative stress is frequent during the first three weeks after calving; the intensive metabolism observed during this period is accompanied by an increase in the amount of reactive oxygen species. While the effects of oxidative stress on the characteristics of the meat is well known, less is known about the relationship between oxidative status of the body (evaluated by the oxidative status of blood) and oxidative status of the milk; it is not yet clear to what extent the direct effect of oxidative stress is reflected in the milk in terms of greater content in oxidized compounds or lower content of antioxidant molecules. However, Andrei et al. (2011) reported a value of glutathione peroxidase higher in mastitic milk than in normal milk. Moreover, was clearly demonstrated that grazing affects oxidative status of milk; Pizzoferrato et al., (2007) proposed a parameter (DAP or degree of antioxidant protection) able to distinguish milk and cheese from grazing and zero-grazing animals; they found a discrimination between goat‘s milk and cheese produced from different feeding systems and concluded that cholesterol was highly protected against oxidative reactions when the herbage was the only feed or was dominant in the goat diet but they also suggest that grazing allows goats to select their favorite herbage and plays a key role in improving animal welfare and milk composition.

Cognitive stress

Mammary epithelial permeability is under hormonal control with glucocorticoids involved for maintenance and formation of mammary TJ. Stelwagen et al. 2000, demonstrated a damage to the integrity of the TJ with consequent increase in mammary epithelial permeability as a result of stress caused by social isolation.

Nutritive stress

One of the most critical moments for the welfare of dairy cattle is the *postpartum*. The negative energy balance, typical of the early stage of lactation, causes changes in milk fat that become particularly rich in polyunsaturated fatty acids resulting from the mobilization of body reserves; the oxidation of these fats can cause unwanted taste.

Environmental stress

Environmental stressors, such as those due to climate changes, housing and interaction with humans have effect on welfare of cows and udder physiology.

Effect of hot stress on welfare of dairy cows (Speroni et al. 2006) and milk composition (Malacarne et al., 2003) has been studied for long time, worldwide. Reduction of milk protein percentage has been observed by several authors. Bernabucci et al. (2002) showed that the reduction of milk protein content observed in the summer was due to the reduction in the casein content (α_s-casein and β-casein) and suggest that these changes might explain the alteration in cheesemaking properties of milk commonly observed during

summer.

There is a general assumption that high standards of cow comfort and the management of clean cows improve milk quality. Some studies have made associations between clean housing, clean cows, satisfactory beds and lower bulk tank somatic cell counts and lower incidence of mastitis (Barkema et al., 1998; Barkema et al., 1999; Ward et al. 2002).

Stress and microbial endocrinology

It is well known that **s**tress enhances the likelihood of infection; classic explanation for this fact is that activation of the sympathetic nervous system under stress leads to the release of neuroendocrine mediators, which may impair innate and adaptive immunity; however, a new discipline, microbial endocrinology, is giving an important role to the bacteria within the ruminant digestive tract to better understanding the mechanisms by which stress influences the pathogenesis of infectious disease (Freestone et al. 2008); Freestone and Lyte (2010) showed that enteric pathogens have evolved systems for directly sensing stress hormones by demonstrating that exposure of enteric pathogens to physiological concentrations of stress hormones can result in increases in growth and changes in expression of virulence factors such as adhesins and toxins. These findings are promising a new approach to better understand how stress influences ruminant physiology and products.

CONCLUSIONS

Relationship between welfare of dairy cows and quality of milk was demonstrated by several authors for many years; the best demonstrated links are the effects of mastitis and oxidative stress on composition, shelf life, sensory and technological characteristics of milk and milk product. In which extent oxidative status evaluated by blood is related to oxidative status of milk should be better studied; effect cognitive stressors on milk quality should be better investigated.

More generally, further interdisciplinary efforts should be made, in the light of the new strategy of the European Commission on animal welfare, new knowledge and emerging disciplines; welfare of dairy cows should be evaluated at farm level by a widely agreed protocol using outcome-based animal indicators; how and how much the animal welfare, measured in such way, affects the quality of milk should be studied by very large surveys and carefully designed experiments.

REFERENCES

Andrei S., Matei S., Fit N., Cernea C., Ciupe S., Bogdan S., Groza I.S. 2011. Glutatione peroxidase activity and its relationship with somatic cell count, number of colony forming units and protein content in subclinical mastitis cows milk. Romanian Biotechnological Letters, Vol.16, No.3: 6209-6217.

Abeni F., Calamari L., Calza F., Speroni M., Bertoni G., and Pirlo G. 2005. Welfare Assessment Based on Metabolic and Endocrine Aspects in Primiparous Cows Milked in a Parlor or with an Automatic Milking System. J. Dairy Sci. 88:3542-3552.

Abeni F., Terzano M.G., Speroni M., Migliorati L., Cappelletti M., Calza F., Bianchi L. and Pirlo G. 2008. Evaluation of Milk Enzymes and Electrolytes, Plasma Metabolites and Oxidative Status in Twin Cows Milked in an Automatic Milking System or Twice daily in a Conventional Milking Parlor. J. Dairy Sci. 91:3372-3384.

Barkema, H.W., Schukken Y.H.,. Lam T.J.G.M, Beiboer M.L., Benedictus G., Brand A.1998. Management practices associated with low, medium and high somatic cell count in bulk milk. J Dairy Sci 81: 1917-1927.

Barkema, H.W., J.D. Van der Ploeg, Y.H. Schukken, T.J.G.M. Lam, G. Benedictus, A. Brand. 1999. Management style and its association with bulk milk somatic cell count and incidence rate of clinical mastitis. J Dairy Sci 82:1655-1663.

Ballou, L. U., Pasquini, M., Bremel, R. D., Everson, T., Sommer, D., 1995. Factors Affecting Herd Milk Composition and Milk Plasmin at Four Levels of Somatic Cell Counts. J. Dairy Sci., 78,10, 2186- 2195.

Barbano D.M., Verdi R.J., Saeman A.I., Galton D.M., Rasmussen R.R., 1987. Impact of mastitis on dairy product yield and quality. 26th NMC Annual Meeting Proceedings. National Mastitis Council, Inc. Arlington, VA, 132.

Barbano, D. M., Ma, Y. Santos M. V., 2006. Influence of Raw Milk Quality on Fluid Milk Shelf Life. J. Dairy Sci. 89,(E. Suppl.):E15–E19.

Bernabucci U., Lacetera N., Ronchi B. and Nardone A. 2002. Effects of the hot season on milk protein fractions in Holstein cows. Anim. Res. 51: 25-33.

Carlucci A, Monteleone E, Braghieri A, Napolitano F. 2009. Mapping the effect of information about animal welfare on consumer liking and willingness to pay for yogurt. J. Sens. Stud.; 24:712–730.

Delamaire, E., and Guinard-Flament J. 2006. Longer milking intervals alter mammary epithelial

permeability and the udder‘s ability to extract nutrients. J. Dairy Sci. 89:2007–2016.
Elbakidze L., Nayga RM Jr. 2012. The effects of information on willingness to pay for animal welfare in dairy production: application of nonhypothetical valuation mechanisms. J Dairy Sci.; 95(3):1099-107.
European Food Safety Authority (EFSA), Panel on Animal Health and Welfare (AHAW),Parma, Italy. Scientific Opinion on the use of animal-based measures to assess welfare of dairy cows1EFSA Journal 2012; 10(1): 2554-2635.
Fernandes A.M., Oliveira C.A.F., Lima C.G., 2007. Effects of somatic cell counts in milk on physical and chemical characteristics of yoghurt. Int. Dairy J. 17, 111-115.
Fox P.F., Law P.L., MacSweeney L.H., Wallace J., 1993. Biochemistry of cheese ripening. In Cheese: Chemistry Physics and Microbiology, Vol.1 General Aspects. P.F. Fox ed. Chapman & Hall, London UK. Page 389-438.
Freeston P.P, Sandrini SM, Haigh RD, Lyte M. 2008. Microbial endocrinology: how stress influences susceptibility to infection. Trends Microbiol. 16(2):55-64.
Freestone P and Lyte M. 2010. Stress and microbial endocrinology: prospects for ruminant nutrition. Animal 4 (7): 1248-57.
Grufferty M.B., Fox P.F.,1988. Milk alkaline proteinase. J. Dairy Res., 55: 609-630.
Ismail B., Nielesen S.S., 2010. Invited review: Plasmin protease in milk: Current knowledge and relevance to dairy industry. J. Dairy Sci. 93: 4999-5009.
Kitchen B., 1981. Review of the progress of dairy science: Bovine Mastitis: Milk compositional changes and related diagnostic tests. J. Dairy Res., 48, 167-188.
Malacarne M., Fossa E., Sandri S., Tosi F., Summer A. & Mariani P. 2003. Seasonal variations of milk quality in Parmigiano-Reggiano cheese manufacture on a period of 10 years. EAAP Technical Series No7. "Interactions between climate and animal production", pp: 100.
Ma Y., Ryan C., Barbano D.M., Galton D.M., Rudan M.A., Boor K.J., 2000. Effects of somatic cell count on quality and shelf-life of pasteurized fluid milk. J. Dairy Sci. 83, 264-274.
Napolitano F, Pacelli C, Girolami A, Braghieri A. 2008. Effect of information about animal welfare on consumer willingness to pay for yogurt**.** J. Dairy Sci.; 91:910–917.
Napolitano F, Braghieri A, Piasentier E, Favotto S, Naspetti S, Zanoli R. 2010. Cheese liking and consumer willingness to pay as affected by information about organic production. J. Dairy Res.*;* 77:280–286.
Pala, A., Atakisi, G. 2012. Effects of animal welfare on sensory acceptance scoring of yogurt. Journal of Applied Animal Research, Volume 40, N.4, pp. 305-310.
Pizzoferrato L., Manzi P., Marconi S., Fedele V., Claps S. and Rubino R. 2007. Degree of Antioxidant protection: A parameter to trace the origin and quality of goat's milk and cheese. J. Dairy Sci. 90: 4569-4574.
Politis I., Ng-Kwai –Hang K.F., 1988. Effects of somatic cell counts and milk composition on cheese composition and cheese making efficiency. J. Dairy Sci. 71, 1711-1719.
Olynk N.J., Tonsor G.T., and Wolf C.A. 2010. Consumer Willingness to Pay for Livestock Credence Attribute Claim Verification. Journal of Agricultural and Resource Economics 35(2):261–280
Shipe W.F., Bassette R., Dean D.D., Dunkley W.L., Hammond E.G., Harper W.J., Kleyn D.H., Morgan M.E., Nelson J.H., and Scanlan R.A. 1978. Off Flavors in milk: Nomenclature, Standards and bibliography. J. Dairy Sci.61:855-869.
Speroni M., Pirlo G. and Lolli S. 2006. Effect of Automatic Milking Sistem on Milk Yield in a Hot Environment. J.dairy Sci. 89:4687-4693.
Stelwagen, K., Farr V. C., and McFadden H. A. 1999. Alteration of the sodium to potassium ratio in milk and the effect on milk secretion in goats. J. Dairy Sci. 82:52–59.
Stelwagen, K., Hopstert H., Van der Werf J.T.N. and Blokhuis H.J. 2000. Short Communication: effects of Isolation Stress on mammary Thigh Junction in lactating dairy cows. J. Dairy Sci.83:48-51.
Ward, W.R., Hughes J.W.,. Faull W.B,. Cripps P.J, Sutherland J.P. and Sutherst J.E.. 2002. Observational study of temperature, moisture, pH and bacteria in straw bedding, and fecal consistency, cleanliness and mastitis in cows in four dairy herds. Vet Rec. 151:199-206.