Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 19, Issue 1, 2019
PRINT ISSN 2284-7995, E-ISSN 2285-3952

COW RAW MILK QUALITY AND ITS FACTORS OF INFLUENCE IN RELATIONSHIP WITH MILK PRICE

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Abstract

The paper presents cow raw milk quality and its influence factors in connection with milk price based on a proper approach of the topic using analysis, synthesis, deduction which helped to establish "the state-of art" in the field of the authors' expertise, emphasizing on the particular factors which contribute to the improvement of milk quality which influence milk price in the EU, USA and other countries. Milk quality is determined by milk composition especially by fat and protein percentages, by the sensory, physical and chemical characteristics. Milk quality is assessed from a hygienic point of view in terms of Total Bacteria Counts (TBC) and Bulk Tank Somatic Cells Counts (BTSCC) whose level should be lower than the maximum thresholds mentioned by EU and USA standards in force, as well as regarding the aflatoxins and antibiotics content. The payment system for the quality of milk and the competition between suppliers and processors for milk supply encourages dairy farmers to produce more milk and of high quality. In this purpose, they have to improve breeding, feeding, hygiene and keep under control mastitis, treatments with antibiotics and other medicines and to produce high quality forages without aflatoxins. The reduction of TBC and BTSCC in raw milk will assure food safety and will increase shelf life of milk and dairy products. Business development in dairy farming has to keep pace with the changes in the internal and international markets. Farmers should become aware that they play an important role in raising milk demand and offer of high quality milk and dairy products.

Key words**:** *milk, quality, criteria of quality assessment, influence factors, milk price*

INTRODUCTION

Milk is a "basic and strategic food which improves life quality and assures food security" [37].
The importance of milk in diet is justified by its chemical composition including, besides water 87 %, 13 % high value nutrients: fats, proteins, carbohydrates, vitamins and minerals, and for this reason milk is considered a complete food recommended to be consumed by all the people [35, 47].
Besides human and animal consumption, milk is an important raw material for food industry, which is one of the most dynamic branch in the economy of many countries.
Milk and milk products are more and more consumed worldwide, being situated on the top of consumption and also among of the most marketed food products [26].
Consumers are aware of the importance of milk in their life and have become more and more interested as milk and milk products to be of high quality. Their perception on milk quality is linked especially to taste, smell, colour, health importance, convenience and production process [40] and also to a longer shelf life [69].
For this reason, both producers, milk processors and retailers pay a special attention to the complex of attributes characterizing milk quality along its food chain from cow to consumer's cup of milk or slice of cheese.
In this context, the purpose of this study was to analyze the actual situation of milk quality and of its determinant factors in dairy farms, the criteria which are taken into consideration for assessing cow raw milk quality in close relationship with milk price offered by processors and farmers' income and profit. The topic is approached not only in general,

but also pointing out specific situations in various countries.

MATERIALS AND METHODS

The review is based on a large range of published books and articles, legal framework in force mainly in the EU and the USA, statistical data, official reports on the topic issued by important authorities in charge,

The authors' opinions and concepts are based on a critical evaluation of the studied materials.

The paper structure includes the following parts: (i)Introduction; (ii)Materials and methods (iii) The situation of milk production, export, import and milk consumption at the world level and in the EU and most important countries; (iv) Factors influencing milk quality at the farm level; (v) Criteria taken into consideration for assessing quality of milk as raw material; (vi) The milk quality standards in the EU and in the USA; (vii) Milk price and its factors of influence; (viii) Conclusions and (ix) References.

Finally the most important conclusions were drawn and also a few recommendation for dairy farmers were made in order to encourage them to improve milk quality and price.

RESULTS AND DISCUSSIONS

The situation of milk production, export, and import, and milk consumption

As long as the demand for milk and dairy products is growing up, dairy market has followed a continuous increasing trend.

In 2018, the world cow milk production reached 510.09 million metric tons being 9.31 % higher than in 2013 [102].

In the same year, the world dairy market output reached 829 million tons (milk equivalent) being by 3.6 % higher than in 2016, while the dairy export accounted for 73.5 million tons (milk equivalent0 being by 8 % higher [17].

This positive trend was determined by the growth of milk production in the major producing countries: India, the EU, the USA, China and also due to the stimulating development strategies applied by Canada, China and Russian Federation. The increased output supported the expansion of dairy exports mainly provided by the EU, the USA, New Zealand, Australia, Argentina and Canada. The imports of dairy products was facilitates by the low self-sufficiency in China, Russian Federation, Mexico, Saudi Arabia, Algeria, Indonesia, United Arab Emirates and Japan (Table 1).

Table 1. World dairy production, export and import in the year 2017 (million tons, milk equivalent)

World dairy production			World dairy export			World dairy import		
Country	Million tons	Market share (%)	Country	Million tons	Market share (%)	Country	Million tons	Market share (%)
World	810.6	100.0	World	71.6	100.0	World	71.7	100.0
India	165.6	20.4	The EU	20.1	28.0	China	13.3	18.5
The EU	165.4	20.4	New Zealand	18.6	25.9	Russian Federation	4.1	5.7
The USA	97.7	12.0	The USA	10.5	14.7	Mexico	3.9	5.4
China	41.3	5.0	Belarus	3.7	5.2	Saudi Arabia	2.9	4.0
Pakistan	40.2	4.9	Australia	3.1	4.3	Algeria	2.8	3.9
Brazil	35.2	4.3	Saudi Arabia	1.4	1.9	Indonesia	2.7	3.7
Russian Federation	30.9	3.8				United Arab Emirates	2.5	3.5
New Zealand	21.3	2.6				Japan	2.2	3.0
Total	597.6	73.4	Total	56.4	80.0	Total	34.4	47.7

Source: Own calculations based on the data provided by [25].

At the world level, cow milk output accounted for 696 million tons in 2017, representing 85.6 % of the world dairy output. The contribution of various suppliers to cow milk production was: Asia 30 %, the EU-28 24 %, the Americas 27 %, Africa 6 % and Oceania 5 % (Table 1).

The world average milk consumption increased by 6.6 % from 106 kg in 2010 to 113 kg per capita in 2017.

The self-sufficiency rate exceeds 100 by 13 % in the EU, by 10 % in Europe, by 9 % in North America, by 189 % in Oceania, it is just equal to 100 in South America and below 100 in Asia (90%), Africa (84%), and Central America (79%) [115].

World milk producer price (USD/100 kg) in the major producing countries was the following one: 56.24 in China, 44.19 in India, 42 in Russian Federation, 40.75 in New Zealand, 39.37 in the EU, 38.8 in the USA, 33.75 in Brazil and 32.3 in Argentina [115].

The EU comes on the 2nd position as milk producer after India and is on the top position as milk exporter.

In 2016, the EU-28 cow milk output on farms reached 162.9 million tons, being by 20.7 % higher than in 2008. The market share of the main producing countries was the following one: Germany 20%, France 15.5 %, United Kingdom 9.1 %, the Netherlands 8.6 %, Poland 8.1 %, Italy 7.3 %, Spain 4.3 %, Ireland 4.2 %, Denmark 3.3 %, Belgium 2.3 % and Romania 2.3 %, all these 11 countries contributing by 85 % to the EU milk production [23].

In 2016, the collection of cow's milk by dairies in the EU accounted for 153.2 million tons, representing 94 % of the milk output. The contribution of various providers to this collection was: Germany 20.9 %, France 16 %, United Kingdom 9.6 %, the Netherlands 9.4 %, Italy 7.5 %, Poland 7.3 %, Spain 4.5 %, Ireland 4.5% and others 20.4 % [23].

Milk price in the EU-28 declined in 2016 after the dissolution of the milk quotas in April 2015. The decline of milk price was higher by 5.68% in 2016 compared to 2015 and by 15.9 % compared to the average registered in the period 2010-2015. However, in 2017, the average milk price in the EU was USD 39.37/100 kg, with the highest milk producer's price in the Netherlands 45.13, Germany 40.88, France 36.61 and Poland 35.72.

In 2017, the EU milk price increased by 25.1 % compared to 2016, in Germany by 38.2 %, in Poland by 31 %, in Netherlands by 28 % and in France by 16 % [115].

Romania comes on the 10th position as milk producer in the EU, contributing by 2.3 % to the EU output. In 2017, Romania achieved 46.6 million hl total milk, of which 40.6 million hl (87.1 %) was provided by cows and buffalos. However, Romania registered a decreasing trend of milk production in 2017, as milk output was by 21.1 % lower than in 2008 (59 million hl). Cow milk also declined by 23.4 % from 53 million hl in 2008 to 40.6 million hl in 2017. This was due to the reduction of cow livestock, despite that sheep and goat livestock had a positive influence [59].

Factors influencing milk quality at the farm level

Milk quality is influenced by a large range of factors which could be classified into two categories: (a)individual factors and (b) environment factors (Table 2).

(a)Individual factors influencing milk quality

Among the factors connected to the animal which produce milk there are: species, breed, family, line, individuality, age, size and shape of the udder, the stage of lactation, and pregnancy.

(i)Species. Milk quality is different from a species to another. Cow milk has 3.8 % fat compared to buffalo (7.5 %), sheep (7.8) and goat milk (3.8). Cow milk has 3.3 % protein compared to 4.8 % in buffalo, 3.6 % in goat, and 5.8 in sheep [101].

(ii)Breed, family, line. Milk quality differs from a breed to another. There are breeds with more fat and protein and also breeds with less fat and protein. This is caused by the genetic inheritance. The two traits: fat and protein have a specific heritability (h^2). For instance, in Wallon Holstein, $h^2 = 0.395$ for fat % and $h^2 = 0.447$ for protein % as found by [3].

Milk of Holstein breed from the USA had 3.6 % fat and 3.2 % protein and 4.7 % lactose for a period of 15 years in the period 1970-1985 [117].

Fat % varies the most from a breed to another, while lactose % varies the least [53, 114].

Jersey and Guernsey breeds have a higher protein %, while Holstein breed has a lower casein % compared to other breeds [36, 53].

A negative correlation, r = -0.3, was found between milk yield and fat percentage which determines as the two characters to be taken into consideration at the same time in selection programmes [36, 53].

In Romania, it was found that Romanian Maramures Brown breed has a higher protein % and a higher dry matter % compared to Romania Black Spotted breed and Romanian Spotted breed. But, the Romanian Black Spotted breed has the highest lactose % and casein % and the lowest fat %, protein % and dry matter % compared to the other two Romanian breeds. Finally, the milk from the Romanian Spotted breed has the highest fat % [98].

The average fat % in the Romanian cattle breeds is the following one: Romanian Spotted 3.8 %, Romanian Black Spotted 3.8 %, Romanian Brown 3.75 %, Transilvanian Pinzgau 3.85 %, Friesian 4.05 %, Simmental 4 % [1].

The American Federation of Cooperatives Select Sires Inc. specified for the following heritability for milk constituents: 0.58 for fat %, 0.51 for protein %, 0.43 for lactose %, 0.10 for somatic cell score, 0.06 for incidence of mastitis. Also, the same source indicated the heritability for udder and teats shape and dimensions as follows: 0.28 for rear udder height, 0.23 for rear udder width, 0.24 for udder cleft, 0.28 for udder depth, 0.26 for teat placement, 0.26 for teat length [42].

Another information source provide the following heritability percentages for a number of traits related to milk quality: 0.5 for protein %, 0.5 for butterfat, 0.10 for mastitis, 0.10 for udder quality, 0.12 for fore udder attachment, 0.10 for fore udder length, 0.25 for rear udder height, 0.7 for rear udder length, 0.33 for suspensory ligament, 0.38 for teat diameter and 0.36 for teat placement [107].

Regarding the influence of family on milk composition and quality, [52] affirmed that the mean values of milk fat, SNF, and protein content are significantly different in case of the groups of paternal half-sisters.

(iii)Individuality. Each animal has its own body development, constitution type, metabolism, functional capacity of the internal organs which could influence milk yield and quality [38].

(iv)Animal age determines first of all milk yield. At the 1st lactation, milk yield is lower and then it increases from a lactation to another up to the 4th lactation and then it declines, a reason to cull the cow as it is not economically effective to keep it. Milk constituents have a high repeatability from a lactation to another, R=0.67, Jersey cows having the highest level, R= 0.71 compared to other breeds where the repeatability ranges between 0.51-0.57 [36, 53].

Also, milk protein declines at the cows which are older than three years [48, 53].

(v)The shape, dimensions and the volume of the udder and teats are very important for assuring a corresponding milk yield and quality. Any deficiency regarding these udder aspects is a reason to cull the cow as mechanical milking can not be done.

(vi)The stage of lactation. Linn (1988) found that "in the first days of lactation when the cow produces colostrum, milk fat percentage is higher, then it declines during the first two months of lactation, and after that, it increases from a lactation to another. The protein percentage has a high value in colostrum and the it declines reaching the level of the normal milk. After ten weeks of lactation, milk protein percentage reaches the minimum level, but then it increases during the lactation and pregnancy"[53].

Fat % is higher in early and late stages of lactation compared to the middle stage. Protein content was not so much affected by lactation stage, but lactose % was seriously affected by pregnancy. [41].

Milk content in minerals such as: Ca, Ph, and Mg has the highest level in colostrum but then it reaches the level of the normal milk [48, 53].

(vii)Pregnancy. This stage of the reproductive cycle could influence the percentage of various milk components. It was noticed that at the beginning of the pregnancy, cow milk has an increased fat and protein percentage, while the lactose percentage is lower [38].

The Holstein Friesian cows pregnant during the three months have a lower milk, fat, protein and lactose yield, while the ones pregnant for eight months registered higher losses due to the pregnancy effect. [65].

(b)Environment factors influencing milk quality

Among the major environment factors which influence milk quality there are: season, temperature level, humidity and rains, soil chemical composition in relation to the cultivated forages and pastures and meadows, the stages of milking, the milking times per day, animal health, nutrition, watering, hygiene condition of the animal and udder, shed, milking equipments, tools, milkers, maintenance systems of the cows etc.

(i)Season is related to milk quality and also with cow feedstuffs whose content in nutrients could determine various levels of fat, protein, fatty acids, minerals etc in milk composition. In summer season, milk fat percentage is lower than in winter season [48, 53].

Milk protein percentage is higher during autumn and winter season and lower in spring and summer seasons [49, 53].

Seasonal changes of fat, protein, sugar content and microbial load in milk were also noticed. In summer, milk is richer in total solids and is poorer in microbes than in winter.[58]. Summer season could reduce the saturated fatty acids compared to the non saturated acids, and for this reason summer milk is more beneficial for humans than in winter season [35].

Milk yield is lower in winter and spring seasons and higher in summer and autumn, but fat and protein percentages are negatively correlated with milk production. Therefore, they are higher in winter and spring, and lower in summer and autumn.[61].

(ii)High temperature, rains, moisture could also affect milk composition. For instance, Toušová *et al*, (2017) noticed that at a high air temperature, daily milk yield and protein percentage had the highest level in Friesian cows (35.94 kg/day and respectively 3.41 % protein). At a lower temperature, it was noticed the reverse. Air humidity has a lower influence on milk quality.[109].

Heat stress in dairy cows could affect milk yield and composition and also milk quality [118].

Bernabucci et al (2002) noticed that "the diminished milk protein content in the summer milk was due to the reduction of the casein content, which, in its turn, was determined by the decline of αs-casein and β-casein content. This aspect explains why cheese properties are affected in summer[7].

(iii)Soil chemical composition in close relationship with the cultivated crops and pastures and meadows could influence milk quality regarding the content in vitamins, minerals etc.[106].

(iv)The stages of milking. At the beginning of milking, fat % is low but then in becomes higher and higher.[38, 53].

(v)The milking times. There are differences between milking three and milking two times. When cows are milked three times, the fat % declines compared to milking two times. But, the opinions of various authors are controversial, as some researchers affirmed that there are no differences.[53].

The frequency of milking does not affect protein percentage.[48, 53].

In the evening milking, milk has a higher fat % compared to the morning milking. Within the same milking, milk has a low fat % at the beginning and then the fat increases to the end of the milking [53].

(vi)Animal health is a very important factor to assure milk production level and also milk quality. Cows could be affected by various diseases such as tuberculosis, brucelosis, mastitis, etc. Almost in all the cases, milk is not good for consumption and cows are milked separately in special hygiene conditions.

Mastitis is generated by low hygiene conditions in the animal shed, poor udder hygiene before and after milking, the non corresponding hygiene of milking equipment before and after milking [112].

Also, mastitis could be caused by oscillating vacuum during mechanic milking, blank milking, parsimonious feeding which reduces the body resistance to various pathogenic agents, udder deficiencies such as: hanging udder, weak ligaments, the non corresponding shape and dimensions of the teats. Also, the high performance cows are the most sensitive to mastitis and for this reason mastitis should be permanently monitorized [96].

Mastitis has two stages: *the subclinic stage*, when somatic cells count increases, the udder does not present visible changes and the treatment could be successfully applied, and *the clinic stage,* when the udder is swollen, it has a higher volume and it is sensitive and milk presents changes for which it can not be used for consumption or processed.[92]

Mastitis is the disease which affects udder health and obviously milk yield and quality.

Milk yield could be diminished by 30-40 % and costs with veterinary services are higher than usual [57, 96].

Mastitis changes milk composition, affecting lactose, protein, casein and fat content [50, 53].

Regarding milk minerals, mastitis decreases Ca, Ph [50] and increases Na and Cl [70].

Mastitis affect cow performance, but also farmer's income and profit as it is the most costly disease of dairy cows [8, 93].

Mastitis could be also determined by farmers' non sufficient knowledge on animal nutrition and feed ratio balance. And also, it could affect not only milk composition, but also to shorten shelf life of marketed milk and dairy products.[57]

Mastitis is one of the most widespread diseases in dairy farms, its frequency varying according to the country, region, production system, and control measures of the disease [116].

Mastitis determines an increased total number of bacteria (TBC) and somatic cells (SCC) in milk, which could affect human health and for this reason milk is tested for the level of TBC and SCC and if the level of these indicators exceeds the milk quality standards established by national authorities, milk is not good for consumption, and has no the corresponding properties for being processed in dairy products [24, 31, 32, 33, 34].

(vii)Nutrition. Feeding is considered one of the most important factors for achieving milk yield and producing high quality milk [58].

A balanced nutrition assures a high quality milk. But, a high performance cow needs a diet rich in energy which could lead to the so called "low-milk-fat syndrome" as affirmed [97].

Sutton (1980) cited by Linn (1988) affirmed that milk composition is affected by "the ratio between forages and concentrates, the type of sugars in cow diet, the form of diet (hay, compound food, silage, green grass etc), the processing of the diet items, the presence of additives, the feeding frequency and method".[53, 105]

Milk protein could be improved using a moderate amount of nondegradable protein, and also using various mixtures of ruminally protected methionine and lysine in high performance dairy cows. An additional 6-7 % fat in the cow diet could lead to the decline both of milk yield and fat and protein content [44].

A balanced diet in minerals could maintain the normal level of minerals in milk. For achieving a high milk yield and quality, maintaining cow health and reproductive performance it is needed to cover cow needs in minerals and vitamins [39].

Feedstuff offered to milking cows has to be of high nutritive value and hygienic. The forage quality could be affected by various factors such as: "plant variety, high temperatures or humidity, insects, spore load, technological deficiencies along the forage chain including harvesting, transportation, storage, handling" as mentioned by [9, 11].

Maize is one of the most used ingredients in dairy cows feeding (silage, compound food etc).

Climate change in Europe has led to an increased risk and occurrence of maize contamination with various fungi, especially with *Aspergillus flavus* and *Aspergillus parasiticus* in the Southern countries of the continent (Italy, the Balkan states) as affirmed [9, 18, 73, 111].

These fungi produce aflatoxins which have a negative impact on feed intake, reproductive performance, milk yield and quality. The B1 and M1 aflatoxins are considered genotoxic, hepato-toxic and carcinogenic for animals and humans [46, 71].

The aflatoxins are stable to heat, cold and light and remanent even in UHT products.[11]

For these reasons, in over 100 countries, there were adopted regulations providing the maximum thresholds for B1 and M1 aflatoxins in animal feed and human food.

The international regulations were issued by Joint FAO/WHO Expert Committee of Food Additives (JEFKA) and in the EU, the Directive 2002/32EC, consolidated version, 27 Feb. 2015 was set up based on the recommendations provided by European Food Safety Authority (EFSA). [111]

(viii)Animal watering should be normal. The lack of water as well as too much water could change milk composition and quality. As long as milk contains 87 % water it is important as a cow to drink a corresponding amount of water to maintain milk content in this nutrient. Water intake depends on cow milk yield, physiological stage, body weight, diet structure, dry matter intake, movement, air temperature, water salinity, etc. Water should be edible and of high quality, not to contain abnormal sulphates, chlorides or nitrates and to have a normal temperature for assuring cow production and milk quality [5].

(ix)Hygiene conditions are very important regarding animal, shed and milking to assure a high quality milk. Cows should be daily cleaned on the back, legs, croup, tail, the udder should be correspondingly washed before and after milking. The shed should be cleaned every days removing the manure, the dirty bedding straw or carpets, urine etc. Milking rules regarding hygiene of the milkers (washed hands, cleaned jumpsuits), milking hygiene (the udder cleaned and washed well, disinfected, rewashed, dried, the massage, the first jets of milk to be collected separately before milking, the perfect hygiene of the milking equipment and parlour before and after milking), the milk tanks to be cleaned, washed, disinfected and to operate at the corresponding temperature during the milk storage till the moment of delivery [6].

(x) Cows' maintenance. Milk yield and quality depends on the cow maintenance system applied in the farm.

The maintenance system has to assure a high comfort to dairy cows and for all their activities: feeding, resting, moving, droppings releasing, milk producing and releasing etc, to assure optimal technological flows, to maintain hygiene and sanitary veterinary conditions, to assure the optimal level of materials and energy consumption, a high quality milk and production and to reduce caretakers and milkers' efforts [38].

Table 2. The factors affecting cow milk quality at the farm level

Individual factors	Environment factors
1.Species	1.Season
2.Breed	2.Temperature level
3.Family	3.Humidity level
4.Line	4.Soil chemical composition related to cultivated forage crops and pastures and meadows
5.Individuality (body development, constitution type, metabolism type, functional capacity of the internal organs)	5.The stages of milking
6.Age	6.The milking times
7.Udder volume, shape, health condition, ligament condition	7.Animal health (tuberculosis, brucellosis)
8.Teats dimensions, shape, health condition	8.Udder and teats health (mastitis)
9.The stage of lactation	9. Nutrition (diet structure and balance, amount, times of administration, feedstuff quality, aflatoxin limits)
10.Pregnancy	10.Watering (amount, times, water quality)
	11.Hygiene conditions (animal and udder hygiene, equipments and tools hygiene, shed hygiene - cleaning and disinfecting, milkers hygiene etc)
	12.Cows' maintenance systems (indoors or outdoors, fixed or free systems)

Source: Own conception based on the studied literature.

During winter season, when usually cows stay in the shed, there were noticed health problems mainly regarding deformed hoofs and lameness due to the long period of stay on uncomfortable stalls, and limited movement. In summer time, animals had less health problems as they went out of the sheds. Shed hygiene is very important to maintain animal health and milk production and quality [37].

Milk quality could be influenced by the maintenance system practice in the farm: the fixed or free system of maintenance indoors or free system outdoors. In Germany, comparing the results regarding fat % and protein % registered by two breeds: Rotbunte and Schwarzbunte grown in the indoors in two systems: fixed systems and free system, there were found the following results: in the fixed system the fat percentage was lower (3.87 % and, respectively, 3.97 %) compared to the free system (3.82 % and, respectively, 3.95 %).

The protein percentage was higher in the fixed system (3.49 %) and lower in the free system (3.46 %) for Rotbunte breed, while in case of Schwarzbunte breed, the protein percentage was smaller in the fixed system (3.45 %) and the same (3.46 %) in the free system [21].

(xi)Milk storage temperature. After milking, milk has to be stored in the tank whose hygiene and functionality has to be perfect to assure a corresponding temperature till milk delivery to processors. Usually, the storage temperature should be between 2°C and 4°C. At a higher temperature than 4°C, the bacteria could develop and the casein fraction could also increase after 72 hours of storage compared to milk stored at 2°C.

The major characteristics and parameters which reflect the quality of raw milk

As raw material milk has to be of a high quality according to milk processors' requirements for enabling them to process milk in various dairy products of high quality and with a long shelf life to cover consumers' needs the best.

The major characteristics and parameters which reflect the quality of raw milk are:

(a)Milk chemical composition.

Sorentino (2010) affirmed that milk composition consists of 87.3 % water, 4.7 % sugars, 3.8 % fats, 3.3 % proteins, 0.9 % minerals and vitamins [101].

In Kliem and Givens' opinion (2011), the chemical composition of whole milk consists of water 88%, protein 3.2 %, fat 3.3 %, carbohydrates 4.8 %, vitamins and minerals. Of all these nutrients, the essential ones for humans are: protein, calcium, phosphorus, iodine, riboflavin, niacin, potassium, A and B12 vitamins [51].

There are many studies on milk composition reflecting milk quality, but almost all the authors pointed out the same components more or less in a similar proportion depending on breed, sample size, region, feeding type etc

Milk composition could be affected by various factors: genetic inheritance, breed, lactation stage, milking, environmental factors of which feeding and hygiene are the most important [7].

(b)Sensory characteristics which could be easily identified are: aspect, consistency, colour, taste, smell.

A high quality milk has to fulfil the following requirements regarding sensory features:

- *aspect:* milk has to be a homogenous opaque liquid, lacked of visible impurities and sediments;

-*consistency*: milk has to have a normal fluid consistency;

-*colour:* milk colour has to be white or frosted white or white and slightly yellow, if milk contains a higher percentage of fat or carotenoid pigments from the forages ingested by the cow. Other colours such as: blue, yellow, pink-red (caused by some specific plants included in the diet or by udder infections), black or with black points etc are considered abnormal, because their appearance is determined by infections and administrated medicines;

-*taste:* milk has to have a specific sweetish taste and flavour of fresh milk due to the content in lactose; when cows are fed with non hygienic forages (altered or affected by fungi) or treated with medicines, milk could have a different taste, a reason not be accepted for consumption; the abnormal tastes are: bitter (due to specific plants used in the diet), salted (when the udder is affected by infections)etc.

-*smell:* milk has to have a specific smell of freshness; under an non proper hygiene conditions, the smell and even the taste could vary from normality; the strange smells could come from forages, manure etc. Also, during the storage period, milk could get a slight acidulous taste and smell due to the fat oxidation. The milk with strange smells and tastes is non used in consumption [21].

(c)Physical characteristics are the following ones:

***-density**:* milk density varies between 1.026 g/cm^3 and 1.034 g/cm^3 at the temperature of 20 ^oC; a normal density indicates that milk is of high quality reflected by a normal chemical composition: 87-88% water and 12-13 % total solids, of which fats 4 % and 9 % solids-non-fat (SNF) which includes: proteins, lactose, minerals and vitamins etc. If milk density is lower than the minimum normal value milk could be suspected of water addition. It is known that 10 % water added to milk could decrease its density by 0.003 g/ cm^3 [67].

-viscosity is important as it is linked to the milk flow properties and also for the appearance and consistency of dairy products; the normal values of viscosity are: 1.74-2.4 cP (centi-poise); the variations of viscosity are determined by milk protein, casein, fat content and temperature. The milk absolute viscosity is 2 cP for whole milk and 1.8 cP for skimmed milk [85].

-opacity is given by the substances existing as a suspension; the higher the fat content in milk, the higher the opacity; opacity could be lower when milk is adulterated with water or forages are rich in water (green grass, grazing, silage etc);

-***specific heat capacity*** of milk ranges between 0.92-0.94 cal/g in the conventional system or 3,935.6 J/kg K or 0.94 (Btu/(lb ^oF)) (Kcal/kg ^oC);

-boiling point of milk varies between 100.2 ^oC and 117 ^oC or 212.3 degrees ^oF (Fahrenheit) at the pressure of 760 mm col Hg; these interval is determined by the content of lactose and minerals; a boiling point lower than the normal value and close to 100 ^oC reflects milk adulteration by adding water;

-***cryoscopic point*** of milk is -0.550 ^oC in average, with limits between -0.530 ^oC and -0.560 ^oC; it should be corrected in addition if milk acidity is 7-8 SH degrees and in minus if the acidity is lower than 8 SH degrees. Any deviation from these limits reflects the adulteration of milk [66].

-***refractive index of milk, RI,*** is 38.5-40.5 refractometric points; it is lower when water is added; also, in case of tuberculosis, the refractive index is by 7-10 degrees smaller than the normal level; also, its limits of variation could be expressed as 1.3422-1.3429, if the refractive index is determined with Zeiss refractometer;

-***superficial tension of milk*** ranges between 50 - 55 dyne/cm^2; it could be higher than 55 dyne/ cm^2 when water is added.

-***specific resistivity of milk or electric conductivity*** varies between 175-200 Ω (Ohm) at 25 ^oC; when the value of this resistivity is smaller, it indicates added water, mastitis or a long length of storage [27, 110].

(d)Chemical properties of milk are:

- ***acidity or pH,*** which varies between 6.33-6.59 due to the content in proteins and minerals; the fresh milk is slightly acid; the alkaline milk after milking reflects that it is infected with proteolytic bacteria; pH level depends on the milk origin, the stage of lactation, being higher at the end of the lactation, cow health and udder health, milkers' hygiene, collection and transportation conditions, and diseases; in case of mastitis, milk had pH over 7.

- ***total acidity or titrable acidity*** ranges between 16.5-19 ^oT (Thörner) or 6.8-7.8 ^oSH (Soxhlet-Henkel) or 16-18 ^oD (Dornic);

-***impurity percentage*** is 1, but if there are more impurities this is caused by the non hygienic conditions during milking when dust, and small particles of forage and waste s could pass into milk; a milk with impurities could be suspected to be infected by bacteria [21, 108, 110].

(e)Hygienic milk quality

Hygienic milk quality is related to: Total bacteria counts (TBC), somatic cell counts

(SCC), Aflatoxins levels and Antibiotics level.

TBC and SCC are the main parameters taken into consideration for assessing milk quality from a hygienic point of view [76].

TBC is an indicator of hygiene of the animal and udder, milking, shelter, and milk storage conditions. The TBC test is used for screening the bacteria level.

SCC is an indicator of udder health and SCC test is used for screening mastitis [56, 68].

The main contamination sources are: animals, arthropods, humans and environment (air, dust, forages, equipments, tools, shelter, storage temperature etc) [21].

Also, season could influence TBC and SCC. TBC was found higher in winter and spring seasons and lower in summer and fall seasons, while SCC was identified lower in spring, but the highest in autumn [68].

Milk obtained from healthy animals has normally a content of bacteria such as: Staphylococus, Streptococus etc [21].

After a hygienic milking, "the TBC level varies between 100- 5,000 cfu. mL^{-1} and SCC is lower than 250,000 mL^{-1} " as affirmed [19, 68].

TBC could be "higher than 107 cfu. mL^{-1} and SCC could be over 106 mL^{-1}" when milk is obtained in bad hygiene conditions as mentioned [67, 99].

A high TBC and SCC have a negative impact on milk quality, milk technological properties [68], shelf life of the pasteurized milk [95], sensory features of cheese [10] and production [103].

For the reasons mentioned above, in many countries are established quality standards for milk hygienic quality.

Despite that there are some differences from a country to another, the standards have a single purpose to assure a high quality milk and milk production for human consumption and food safety and security.

Table 3. The main characteristics and parameters reflecting raw milk quality

Chemical composition	Sensory characteristics	Physical characteristics	Chemical characteristics	Hygienic quality
-Fat %	-Aspect	-Density	-Acidity (pH)	-Total Bacteria Counts (TBC) or Bactoscan
-Protein %	-Consistency	-Viscosity	-Titrable acidity	-Bulk Tank Somatic Cell Counts (BTSCC)
-Water %	-Color	-Opacity	-Dry matter	-Aflatoxin level
-Carbohydrates %	-Taste	-Specific heat capacity	-Impurities	-Antibiotics level
-Minerals	-Snell	-Boiling point		
-Vitamins		-Freezing point		
		-Refractive index		
		-Superficial tension		
		-Specific resistivity		

Source: Own design.

The milk hygienic quality in the EU countries is based on a legal framework including the following regulations: Council Directive 92/46/EC/1992 [14], Council Directive 94/71/EC/2013 [15] amending Directive 92/46/EC/1992, Council Directive 2002/99/EC [16], Regulation (EC) No 178/2002, [86], Regulation (EC) No 852/2004 [86], Regulation (EC) No 853/2004 [88], Regulation (EC) No 854/2004 [89], Regulation (EC) 882/2004 [90], EU Commission Regulation No.1662/2006 amending Regulation (EC) No. 853/2004 [24], Commission Regulation (EC) No 1664/2006 amending Regulation (EC) No 2074/2005 [12], Commission Regulation (EU) No 605/2010 [13].

This legislation is in force in all the EU member states [43], but also in other European countries (Norway and Switzerland), Australia [15], New Zealand [100] and Canada [100].

In the EU, the milk quality standards for milk hygienic quality are:

(a)maximum 100,000 TBC/ml or 100,000 cfu.mL^{-1} (5.00 log 10 cfu.mL^{-1}) in bulk tank. In Bactoscan units, this means maximum 100 units for bactoscan/mL in the collected milk (1 unit of bactoscan = 1,000 bacteria/mL).

However, TBC should be maintained below 15,000 bacteria/mL or 15 units of bactoscan to reduce the risk of mastitis, to improve milk quality, to prolong the milk products shelf life and to strengthen the ability of milk to be processed into cheese.

The total bacteria counts (TBC) in the EU 100,000 bacteria/mL is also the superior threshold for Grade A milk in the USA [2].

(b)maximum 400,000 mL^{-1} BTSCC is the limit adopted in the EU, Australia, New Zealand and Canada.

In Brazil, the maximum BTSCC level is 1,000,000 cells/mL^{-1}.[20, 43, 54, 55, 91, 100].

Since May 16, 2018, the EU established the Hygiene Regulations with regard to the testing of raw milk for Plate Counts (TBC) and SCC.

For cow raw milk, the Plate count is determined at 30 C degrees per ml and should be ≤ 100,000 per mL and should be determined rolling geometric average over a two-month period with at least two samples per month.

The SCC is determined rolling geometric average over a three-month period with at least one sample per month, unless the competent authority specifies another methodology to take into account of seasonal variations in production levels. The maximum limit is 400,000 cells/mL [20].

In the USA, the milk quality standards were and are regulated by the following legal framework: FDA. 1991. Actions of the 1991 National Conference on Interstate Milk Shipments, August 22 memorandum from Milk Safety Branch [29], the ordinances issued by US Department of Health and Human Services, Public Health Service, Food and Drug Administration. Washington, DC: FDA. 1993. Grade “A” Pasteurized Milk Ordinance, 1993 Revision. US Department of Health and Human Services, Washington, DC [30], FDA. 2009. Pasteurized Milk Ordinance, PMO, Grade “A” Pasteurized Milk Ordinance, 2009 Revision [31], FDA, 2011, Grade “A” Pasteurized Milk Ordinance 2011[32], FDA, 2013, Grade “A” Pasteurized Milk Ordinance [33], FDA, 2015, Grade “A” Pasteurized Milk Ordinance 2015 [34, 63].

According to the regulations in force, the milk hygienic quality standards in the USA are:

(a) maximum 100,000 cfu for Grade A milk and **maximum 300,000 cfu for Grade B** milk (b)**maximum 500,000 cells/Ml for Grade A** milk and **750,000 cells/mL for Grade B** milk.

Taking into consideration the importance of milk quality for food safety, and to compile with the EU standards for facilitating the trade with dairy products, in the USA there are made efforts to reduce the threshold of 750,000 SCC/mL.

Norman *et all*, (2000, 2011) mentioned that in the most herds SCC is much below legal bulk tank thresholds and could easily meet lower limits, for instance: 500,000 - 400,000 cells.mL, therefore it is possible to reduce the current legal limit of 750,000 SCC/mL [62,63].

However, a few American states diminished the maximum threshold of BTSCCs as follows: to 600,000 in California, 400,000 in Idaho, 500,000 in Oregon and 400,000 in Washington.

In milk shipments, in the USA, BTSCCs are monitored based on the standards established by U,S, Pasteurized Milk Ordinance (PMO) which provides maximum 750,000 cells/mL for Grade A milk shipments [20, 34].

Because the EU regulations do not compile with the American regulations regarding BTSCC, there are some problems regarding the milk products which are subject of export/import between the two trade partners.

Despite the efforts made to diminish the maximum threshold from BTSCC 750,000 to 400,000 cell/mL, the PMO did not change the legal framework, and this created problems to the exports of dairy products from the USA to the EU.

For this reason, Norman *et al*, (2011) affirmed that the U.S. milk producers have four consecutive rolling three-month SCC means greater than the 400,000 cells/mL limit cannot export milk to the EU unless derogation is requested and approved. If derogation is not approved, the milk supplier must suspend, segregate or discontinue certification" [63].

Also, Norman *et al,* (2011) observed that despite both in the EU and in the USA the bacterial limit TBC is the same, 100,000 cells/mL, the method of calculation does not compile. In the EU, it is used a 2-month geometric mean based on a minimum of two standard plate counts performed per month. The EU bacterial limit 100,000 cells/Ml is the limit for Grade A milk in the USA, but in the U.S. the calculation is made differently [63].

Despite that in 2011, it took place the National Conference on Interstate Milk Shipments (NCIMS), on this occasion it was not taken any decision to reduce the current BTSCC maximum limit, but there were discussed and issued promising outcomes on two topics: "reasonable regulations in the Pasteurized Milk Ordinance (PMO) that will allow it to align with pending requirements of the Food Safety Modernization Act (FSMA)" and "sampling criteria and rapid test methods to expand the requirements for testing raw milk for additional drug residues".[60].

In the USA, based on the results obtained within the Dairy Herd Improvement (DHI) somatic cell testing during the year 2017, Norman *et al*, (2017) [64] affirmed that in 2017 compared to the year 1995, the number of herd test-days was 149,130 by 44 % lower, the average herd size was 202.5 cows/herd 4.05 times higher, the average daily milk yield reached 78.1 lb (pounds) being by 19.6 % higher, the national average herd test-days was 197,000 cells/Ml by 26 % lower, and the the percentages of the herd test-days higher than the 4 groups of SCC thresholds 750,000, 600,000, 500,000 and 400,000 was 1.6 %, 3.2 %, 5.7 % and, respectively 10.8%, much lower than in 1995 (Table 4).

Table 4. Comparative results regarding the average herd test-days, average herd size, average SCC/herd and the percentage of herd test-days over 4 SCC thresholds in the USA in 2017 versus 1995 based on the data of the herds enrolled in Dairy Herd Improvement Programme

	2017	1995	2017/1995%	Annual trend in the period 1995-2017 based on linear regression
Number of herd test-days	149,130	265,844	56.09	-6,011
Average herd size (cows/herd)	202.5	50	405.00	7.3***
Average daily milk yield (lb/herd)	78.1	65.3	119.60	0.6***
Average SCC per herd (cells/mL)	197,000	304,000	64.80	-6.8***
Percentage of herd test-days with SCC higher than:				
750,000 cells/mL	1.6	4.1	30.02	-0.2***
600,000 cells/mL	3.2	9.3	34.40	-0.4***
500,000 cells/mL	5.7	16.0	35.62	-0.7***
400,000 cell/Ml	10.8	27.2	39.70	-1.0***

***Significant for $p<0.001$.
Source: Own adaptation based on [64].

These positive results reflected the efforts of the dairy farmers to improve farm management and apply a severe culling to reach a higher milk quality.

The same authors found that there are differences among the states determined by climate conditions, especially concerning temperature and moisture, but also due to farm size and the practices used for mastitis control. The Northern, Eastern and Western states of the USA registered lower SCC/mL than the national average level, while the South-Eastern states recorded a higher SCC [64].

Milk price and its factors of influence

Milk price is influenced by many internal and external factors (Table 5).

(a)The internal factors influencing milk price are:

(i)***Milk quality*** regarding ***sensory features, physical and chemical properties, chemical composition*** especially concerning fat and protein percentages, as discussed in the previous paragraphs, and also ***milk hygienic quality*** given by a smaller TBC and BTSCC than the maximum limits admitted by the standards in force, reflecting a good animal health and welfare, a corresponding feeding with high quality forages without aflatoxins, a rigorous mastitis and antibiotics control, a corresponding hygiene of the cow shelters, animals, milking and storage.

Raw milk price depends on milk quality, as it is a close relationship between these two indicators which are of high interest to farmers who have to permanently improve milk quality in order to get a better price destined to cover production cost and assure profit.

Milk quality differs from a farm to another and as a result milk price as well [113].

The improvement of milk quality is obviously a compulsory goal of dairy farmers, because they could get incentives (bonuses, premiums etc) helpful from an economic point of view [8].

Erickson (2016) and Bewley (2018) consider that "the level of bonuses, premiums etc, farm size and milk yield are the triad which could increase the dairy farmers' income and profit" [22].

(ii)***The amount of marketed milk*** in close relationship with milk yield and the number of milking cows in the farm could influence milk price. Higher amounts of commercialized milk based on the contracts concluded with milk processors could attract higher milk prices. However, the quantity of sold milk varies according to season which also has a deep impact on milk composition as mentioned in the above discussions [72, 80].

(iii)***The marketed milk pattern*** is another factor influencing milk price. When the variations of the amounts of sold milk are smaller from a delivery to another, the dairy farmers could benefit of a higher price. For this reason, dairy farmers have to take measures to assure a flat production trend and at the same time to keep production costs under control as milk price to cover them [78].

(iv)***Farm management*** depending on knowledge, managerial skills, practical experience of the dairy farmer regarding applied technologies (cropping, breeding, reproduction, feeding, production etc) and financial aspects regarding gross income, gross margin, production costs, profit [74, 75, 79].

(v)***Milk marketing strategy*** is closely linked to marketed milk, milk quality and market price [45, 82, 83].

(b)The external factors influencing milk price are:

(i)***Geographical area*** where the farm is situated and is operating which has a deep influence on milk supply from a quantitative and qualitative point of view due to the specific climate and soil conditions, and all these could influence milk price.

(ii)***Milk supply pattern*** in the area is another determinant of milk price. Milk supply should be consistent during the year as the domestic market requires. Any variation in milk offer could induce a different milk price.

(iii)***Competition among dairy farmers*** operating in the same area is also an incentive to increase milk supply and get a better price at delivery. The difference of milk price could be 10-20 % from a farmer to another even they sell milk to the same processor [113].

(iv)***Milk payment system*** including incentives (bonuses, premium, penalties etc).

The incentives offered for milk yield stimulate dairy farmers to produce and commercialize more milk. *The incentives offered for milk quality* have also a positive effect on milk price and farmers' income. *The loyalty incentives* are also in the benefit of the farmers enabling them to continue to produce and deliver milk of high quality to the same processor and increase their income.

The penalties for exceeding the maximum thresholds of the quality standards for TBC and BTSCC have the reason to encourage dairy farmers to improve milk quality.

Milk payment system continue to have a substantial effect on the reduction of TBC and BTSCC and a higher and higher percentage of dairy farmers deliver raw milk according to the quality standards and below them.[63, 94, 104].

(v)Milk processors financial situation regarding milk processing costs, sales, profit and profitability rate in close relationship with milk supply volume attested by the delivery contracts concluded with dairy farmers and milk payment strategy which has to assure a balance between the shareholders' profit and the payments to dairy farmers which are destined to maintain a secure supply level.

From this point of view, each processor has to make a deep analysis of milk market before making the decision what milk price to offer in order to manage the competition among processors for milk supply. Therefore, milk processors themselves are interested as dairy farmers to produce more milk and of higher quality and their business to be profitable in order to benefit of a permanent delivery to processing industry.

(vi)*Milk price trends in the domestic and international market* could influence the decision of milk processors regarding milk price offer to their suppliers.

The international trade with dairy products, the demand/offer ratio, the export/import ratio on various markets have a impact on prices. For this reason, processors have to be permanently informed on the evolution of world prices before making the decision how much to pay for raw milk supply [77, 80, 84, 113].

Table 5. Milk price factors of influence

On-farm factors	Off-farm factors
-Milk quality	-Geographical area
-Marketed milk	-Milk supply pattern
-Marketed milk pattern	-Competition among dairy farmers
-Farm management	-Milk payments system
-Milk marketing strategy	-Milk processors' financial situation
	-Milk processors price offer
	-Milk price trends on the domestic and international markets

Source: Own design.

CONCLUSIONS

The paper emphasized the importance of raw milk quality and its factors of influence in connection with milk price. The purpose was to identify the reasons why milk price is different between countries, regions, farms and processors.

Also, this analysis pointed out what dairy farmers have to make to improve milk quality in order to get a better and satisfactory price for covering milk cost and assure a profit.

The study allowed to issue the following recommendations to dairy farmers to improve milk quality and price:

-to improve breeding programmes in their herd by a high selection pressure and corresponding mating;

-to produce and administrate high quality forages and a balanced diet to dairy cows for increasing production and fat and protein percentages;

-to assure a corresponding comfort and hygiene in the shelters, for cows and udder, milk equipments, milking, storage;

-to keep permanently under control the treatments with antibiotics and other medicines remaining in milk and apply a rigorous control of mastitis;

-to increase milk yield and cow livestock in order to deliver a higher amount of high quality milk;

-to compensate the seasonal variation of milk production by producing a high quality of milk richer in fat and protein and with TBC and BTSCC below the maximum thresholds imposes by the regulations in force;

to entirely respect the regulations regarding milk quality;

-to be aware of the stronger and stronger competition on milk market among suppliers and processors for a high quality offer;

-to keep an eye on the milk price trend both on the internal and external markets in order to establish a more effective strategy for developing their business under profitable condition.

As a final conclusion, each dairy farmers should be aware of his role in increasing milk demand and supply of high quality milk and dairy products.

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