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SHORT COMMUNICATION

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SEASONAL VARIATION IN THE QUALITY PARAMETERS OF MILK FROM AN EXTENSIVE, SMALL FAMILY FARM

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ABSTRACT

This research aimed to determine the hygienic quality, physicochemical properties and technological suitability of milk obtained in an extensive, small family farm in western Poland in the spring-summer (grazing) and autumn-winter (indoor) seasons. The farm was operated in the traditional manner where animals spend 7/24 on the pasture in the spring-summer season. The study was performed on forty-eight samples of bulk tank milk collected once a week over one year from 17 cows of the old local Polish black and white lowland breed. Milk was tested for somatic cell count, total bacterial count, basic composition, density, vitamin C content, rennet coagulation time, pH and colour in the CIE L*a*b* system. In the autumn-winter season, a higher somatic cell count, higher protein, fat and lactose levels, longer coagulation time and lower colour parameter a* values were found compared with the spring-summer period. However, no differences as regards the colour parameters L* and b* and vitamin C content were observed between the seasons. Highly significant negative correlations between the colour of the milk and the total bacterial count and somatic cell count were found ($P \leq 0.01$). High somatic cells count in studied milk highlights that mastitis and milking hygiene are still a challenging task in small family farms.

Key words: extensive dairy farming, seasonality, hygienic quality, milk colour, vitamin C

INTRODUCTION

To feed the world and do it sustainably, an urgent and radical shift in our food systems is necessary. Family farmers are at the heart of this issue as they provide the majority of the world's food [FAO and IFAD 2019]. In 2019 The United Nations' Food and Agriculture Organisation (FAO) launched the Decade of Family Farming. According to FAO family farming offers a unique opportunity to ensure food security, improve livelihoods, better manage natural resources, protect the environment and achieve sustainable development, particularly in rural areas.

Family farms dominate the structure of EU agriculture in terms of their numbers. In 2016 within the EU, there were 9.9 million farms classified as family farms from which 1.4 million were located in Poland. To increase their viability, the farmers often consider alternative activities and income streams. Converting to organic is one of the options; however, it requires financial investments and a lot of time and work. Thus, another diversification options are often considered.

Selling value-added milk and milk products on-farm is a popular choice for extensive small family farms (SFF) in Poland. The number of consumers who search for fresh, natural, unprocessed food of high nutritional and biological value is increasing [Cais-Sokolińska et al. 2015, Schwendel et al. 2015]. The commodities form local SFFs are often perceived by consumers similarly to the organic products in terms of taste, food safety, animal welfare and reduced environmental impacts and are widely recognised by consumers.

Currently, particular attention is paid to the positive impact of SFFs and organic farming on biodiversity, especially on farmland birds, predatory insects, spiders, soil organisms and the arable weed flora [Schader et al. 2014,

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Alothman et al. 2019]. It is stressed, based on numerous studies comparing milk from organic farms with that from conventional farms, that organic milk is unique in that it is safe and has both a high content of bioactive compounds and the sensory qualities which are valued and sought after by consumers [Gutiérrez et al. 2013, Kouřimská et al. 2014]. However, very little research has been conducted on the quality of milk produced on SFFs that are not certified as organic.

The quality of milk is determined by a combination of genetic and environmental factors and the interaction between them. One of the environmental factors is seasonality, which is closely related to the diet and welfare of animals. The available literature contains a very limited number of publications on the impact of that factor on the quality parameters of milk in both organic farms and SFFs and the results of these studies are often inconsistent [Butler et al. 2011, Cziszter et al. 2012, Gulbe and Valdovska 2014].

This research aimed to determine the hygienic quality, physicochemical properties and technological suitability of milk obtained in an extensive, small family farm in Poland in the spring-summer (grazing) and autumn-winter (indoor) seasons. The farm was operated in the traditional manner where animals spend 7/24 on the pasture in the spring-summer season and were not certified as organic in the time of samples collection.

MATERIAL AND METHODS

The study was conducted according to the provisions on animal protection. The study was carried out on a small, 30-ha family farm located in western Poland keeping a herd of 17 dairy cows of the old local Polish black and white lowland breed. Milk was processed on-farm into ripening cheese, cottage cheese, yoghurt, butter and sour cream.

The study was performed on 48 samples of bulk tank milk collected once a week over one year from 17 cows in the spring-summer season (April to September) and in the autumn-winter season (October to March). The cows spent the entire spring-summer season on the pasture (7/24) and had permanent access to liquid whey received as a by-product from cheese production. Moreover, during milking, the cows were given concentrated feed containing barley and oat bran. In turn, in the autumn-winter season, the cows were tethered and kept on deep litter. Straw bedding was applied daily, while the manure was removed once a week.

In autumn-winter season animals were fed hay and haylage, with the addition of concentrated feed. Once a day they were also given whey. The cows were milked in the morning and in the evening using a bucket milking machine, following good manufacturing and hygiene practices. Milking procedure consisted of fore-stripping, disinfection, and post-milking dip. For analysis milk was collected from the morning and evening milking, after thorough mixing. Samples were getting into 100 ml sterile containers and cooling to 4°C. The milk was tested for somatic cell count, total bacterial count, basic composition, density, colour, vitamin C content and rennet coagulation time. The analyses were carried out in duplicate.

The basic chemical composition and density of the milk were determined using a Lactostar analyser (Funke Gerber, Germany). Total bacterial count (TBC) and somatic cell count in milk (SCC) were determined using a BactoCount IBCm apparatus (laser-based flow cytometry; Bentley, Minnesota, USA). Acidity was analysed using a portable Handylab 2 (Schott Geräte, Meinz, Germany) apparatus with a glass-calomel electrode (Schott L68880). Vitamin C analysis was conducted by the method proposed by Omaye et al. [1979]. The colour of milk samples was measured in triplicates in the CIE L*a*b* system, where L* represents lightness, a* represents the colour's position between green (–a*) and red (+a*), and b* represents the colour's position between blue (–b*) and yellow (+b). The Minolta CM 5 Colorimeter (Minolta Corp., Osaka, Japan) with an illuminant C and a 2° observer was used. Rennet coagulation time (RCT) was measured using the method by Alais [1984].

Analysis of the results was conducted using the STATISTICA package v. 13.3 (Statistica 2017). Student's *t*-test was used when comparing the averages milk quality parameters for two seasons. The levels of significance for Student's *t*-test were $P \leq 0.05$ (*) and $P \leq 0.01$ (**). The data relating to the TBC and SCC in the milk was subjected to logarithmic transformation before statistical verification. Moreover, Pearson correlation coefficients were calculated for selected parameters for individual seasons and the overall period covered by the study. The levels of significance of correlations were as follows: $P \leq 0.05$ (*) and $P \leq 0.01$ (**).

RESULTS AND DISCUSSION

Average daily yield of the herd in the spring-summer season was 161 kg of milk, while in the autumn-winter season 265 kg. Tables 1–4 show mean values and standard deviations of particular quality parameters of milk both for individual seasons and for the overall period covered by the study. TBC and SCC are important parameters of milk hygiene. The factors influencing the hygienic quality of milk include milk yield as well as organisational and technological factors [Skrzypek et al. 2004, Cziszter et al. 2012, Hamed et al. 2012, Keskin and Atasever 2013].

A high seasonal variation in all milk constituents, except for mineral salts, was observed (Table 2). In the

Table 1. Hygienic quality of milk depending on the season (Mean value ± Standard deviation)

Tabela 1. Jakość higieniczna mleka w zależności od sezonu (średnia wartość ± odchylenie standardowe)

Traits Cecha	Season – Sezon		
	spring – summer wiosna – lato	autumn – winter jesień – zima	total ogółem
TBC (× 10^3 mL^{-1})	156 ±104	218 ±136	187 ±120
SCC (× 10^3 mL^{-1})	251 ±146 ^{a}	426 ±300 ^{b}	339 ±223

TBC – total bacteria count, SCC – somatic cell count, ^{A}, ^{B} – statistical significance at $P \le 0.01$, ^{a}, ^{b} – statistical significance at $P \le 0.05$.
TBC – ogólna liczba bakterii, SCC – liczba komórek somatycznych, ^{A}, ^{B} – różnica statystycznie istotna, $P \le 0{,}01$, ^{a}, ^{b} – różnica istotna, $P \le 0{,}05$.

Table 2. Basic composition of milk (%) depending on the season (Mean value ± Standard deviation)

Tabela 2. Skład podstawowy mleka (%) w zależności od sezonu (średnia wartość ± odchylenie standardowe)

Traits Cecha	Season – Sezon		
	spring – summer wiosna – lato	autumn – winter jesień – zima	total ogółem
Non-fat dry matter Sucha masa beztłuszczowa	8.62 ±0.18 ^{A}	9.09±0.19 ^{B}	8.86 ±0.19
Fat – Tłuszcz	3.19 ±0.34 ^{A}	3.79±0.50 ^{B}	3.49 ±0.42
Protein – Białko	3.21 ±0.07 ^{A}	3.40±0.08 ^{B}	3.30 ±0.08
Lactose – Laktoza	4.63 ±0.11 ^{A}	4.89±0.12 ^{B}	4.76 ±0.11
Minerals – Składniki mineralne	0.87 ±0.03	0.86 ±0.05	0.86 ±0.04

^{A}, ^{B} – statistical significance at $P \le 0.01$ by Student's *t*-test.
^{A}, ^{B} – różnica statystycznie istotna, $P \le 0{,}01$, oznaczona testem *t*-Studenta.

Table 3. Milk colour in the CIE (L*a*b*) system depending on the season (Mean value ± Standard deviation)

Tabela 3. Barwa mleka w systemie CIE (L*a*b*) w zależności od sezonu (średnia wartość ± odchylenie standardowe)

Traits Cecha	Season – Sezon		
	spring – summer wiosna – lato	autumn – winter jesień – zima	total ogółem
L*	88.81 ±0.29	89.02 ±0.43	88.92 ±0.36
a*	–3.25 ±0.36 ^{A}	–2.90 ±0.46 ^{B}	–3.08 ±0.41
b*	15.03 ±0.80	14.48 ±1.50	14.76 ±1.15

L* – lightness, a*– redness, b*– yellowness, ^{A}, ^{B} – statistical significance at $P \le 0.01$ by Student's *t*-test.
L* – jasność, a* – nasycenie barwą czerwoną, b* – nasycenie barwą żółtą, ^{A}, ^{B} – różnica istotna, $P \le 0{,}01$, oznaczone testem *t*-Studenta.

autumn-winter season, the milk produced by the cows had a higher protein, fat and lactose content ($P \le 0.01$), which is consistent with the results of most studies [Cziszter et al. 2012, Bernabucci et al. 2015]. The lower protein content of milk in the spring-summer season is explained by a lower share of concentrated feed in the feed ration of the cows compared with the autumn-winter season. Green fodder contains more fibre and less starch, which results in reduced production of propionic acid in the rumen, and, consequently, reduced milk protein content. In turn, other studies showed that milk from grass-fed cows had a higher protein content, calling this phenomenon a 'specific grass effect' [Alothman et al. 2019].

Milk colour is an important assessment parameter. It has an impact on how milk products, especially butter and cheese, are perceived by consumers. Consumers in different countries search for lighter or darker products, depending on their habits [Walker et al. 2013]. Milk colour is associated with the presence of the colloidal calcium phospho-caseinate complex, insoluble calcium phosphate and the scattering of light by fat globules. Milk pigments such as fat-soluble carotene and riboflavin in

Table 4. Milk density, pH, vitamin C content and rennet coagulation time depending on the season (Mean value ± Standard deviation)

Tabela 4. Gęstość mleka, pH, zawartość witaminy C oraz czas koagulacji pod wpływem podpuszczki w zależności od sezonu (średnia wartość ± odchylenie standardowe)

Traits Cecha	Season – Sezon		
	spring – summer wiosna – lato	autumn – winter jesień – zima	total ogółem
Density, $g \cdot cm^{-3}$ – Gęstość, $g \cdot cm^{-3}$	1.033 ±0.001 ^{A}	1.034 ±0.001 ^{B}	1.033 ±0.001
pH	6.79 ±0.03	6.75 ±0.12	6.77 ±0.08
Vitamin C, $mg \cdot 100\ mL^{-1}$ – Witamina C, $mg \cdot 100\ mL^{-1}$	3.66 ±1.09	3.97 ±1.40	3.81 ±1.25
RCT, sec.	316 ±44 ^{A}	389 ±64 ^{B}	353 ±54

RCT – rennet coagulation time; ^{A}, ^{B} – statistical significance at $P \leq 0.01$ by Student's *t*-test.
RCT – czas koagulacji pod wpływem podpuszczki; ^{A}, ^{B} – różnica statystycznie istotna, $P \leq 0,01$, oznaczone testem *t*-Studenta.

milk serum may also influence the colour of milk. Other factors which may affect the colour of milk include the nutrition of cows, diseases and physiological factors associated with milk production [Coppa et al. 2019]. An instrumental milk colour analysis showed seasonal variation only in parameter a* values; ($P \leq 0.01$; Table 3). Milk obtained in the autumn-winter season had a significantly higher degree of greenness compared with that obtained in the spring-summer season. It was probably associated with the diet of the animals and with the total bacterial count and somatic cell count in the milk. There were numerous significant correlations between the colour of the milk and its hygienic quality and basic composition (Table 5), including highly significant negative correlations between parameter a* and the TBC ($r = -0.747$**) and the SCC ($r = -706$**) in the grazing season, and a positive correlation between parameter a* and milk fat content ($r = 0.649$**).

The production season did not affect milk pH (Table 4). The results obtained (6.79–6.75) indicate that the milk was of the correct quality and are consistent with the findings of other studies on milk from cows kept in traditional farms [Barłowska et al. 2013].

The value of milk density depends on the density of individual milk constituents. In our study, the density of the milk analysed was $1.0335\ g \cdot cm^{-3}$. The density of the milk collected in the autumn-winter season was significantly higher compared with the milk collected in the spring-summer season ($P \leq 0.01$; Table 4), which was associated with the chemical composition of the milk. The results are consistent with the results of a study by Cziszter et al. [2012].

The vitamin C content of the milk analysed was not found to be dependent on the season (Table 4). To the best of our knowledge, this is the first report on seasonal changes of vitamin C in cow milk obtained in SFF. However, studies on mares' milk found that the vitamin C content did not depend on the season in which the milk was collected, but on how it was stored [Markiewicz-Kęszycka et al. 2014]. The literature on the subject shows that vitamin C content is not subject to seasonal variation as cows can synthesise ascorbic acid [Weiss and Hogan 2007]. In the case of cattle requirements for vitamin C are met by tissue and bacterial synthesis in the digestive tract and mammary gland cells. Vitamin C is regarded as a valuable bioactive substance. However, cows' milk is considered to be a poor source of this vitamin. It should be stressed that the analysed milk contained four times more vitamin C ($3.81\ mg \cdot 100\ mL^{-1}$) than milk from conventional farms ($0.94\ mg \cdot 100\ mL^{-1}$) [Park et al. 2007]. Vitamin C cannot be synthesised by humans and is one of the most important vitamins with antioxidative properties. Along with vitamins D, A and beta-carotene, it helps prevent the oxidative stress and protects polyunsaturated fatty acids from uncontrolled peroxidation [Jóźwik et al. 2012].

The coagulation properties of milk depend on several parameters, including acidity, the concentration of proteins, especially casein, the ratio of casein to whey protein and the content of minerals, including calcium, phosphorus, magnesium and citrates [Ketto et al. 2017, Ho et al. 2018]. The analysis of the coagulation properties of the milk studied showed higher technological suitability of the milk collected in the spring-summer season compared with that collected in the autumn-winter season ($P \leq 0.01$; Table 4). Those findings were consistent with the results obtained by Barłowska et al. [2012]. The coagulant properties of milk are also associated with the composition of pasture sward. The presence of clover grass in the pasture has been shown to worsen milk coagulation [Hermansen et al. 1994]. Similarly, Bernabucci et al. [2015] showed in the summer, especially during hot weather, a deterioration in milk coagulation properties, which the authors explain by changes in the casein protein fraction, especially αS-CN and β-CN.

Table 5. Pearson correlations between colour parameters (a*b*) and the TBC and SCC and the basic composition of milk

Tabela 5. Korelacje Pearsona pomiędzy barwą a TBC, SCC i składem podstawowym mleka

Item – Wyszczególnienie	Season – Sezon				
	spring – summer wiosna – lato		autumn – winter jesień – zima		total ogółem
	a*	b*	a*	b*	a*
TBC	–0.747**	–0.618**	0.432*	NS	NS
TBC ($\log_{10}$)	–0.660**	–0.520*	0.550**	NS	NS
SCC	–0.706xx	–0.589**	NS	NS	NS
SCC ($\log_{10}$)	–0.658**	–0.562**	0.495*	NS	NS
Non–fat dry matter – Sucha masa beztłuszczowa	NS	0.466*	NS	NS	0.421**
Fat – Tłuszcz	0.649**	NS	0.703**	0.464*	0.741**
Protein – Białko	NS	0.495*	NS	NS	0.386**
Lactose – Laktoza	NS	0.485*	NS	NS	–0.373*
Minerals – Mineralne	NS	NS	0.504*	NS	NS

a*– redness, b*– yellowness, TBC – total bacteria count , SCC – somatic cell count, ** – correlation significant at P ≤ 0.01, * – correlation significant at P ≤ 0.05, NS – not significant.
a* – nasycenie barwą czerwoną, b* – nasycenie barwą żółtą, TBC – ogólna liczba bakterii, SCC – liczba komórek somatycznych, ** – korelacje istotne (P ≤ 0,01), * – korelacje istotne (P ≤ 0,05), NS – korelacje nieistotne.

Moreover, the enzymatic coagulation time of milk may increase together with increasing SCC [Sert et al. 2016]. This may probably explain the longer coagulation time observed in our study in the autumn-winter season; however, it was not confirmed statistically. Our analyses showed a correlation between rennet coagulation time and the content of minerals and vitamin C; the correlations were statistically significant, negative and were, respectively, r = –0.466* and –0.429*.

The total bacterial count in the milk, in the overall period covered by the study, was 187 thousand per ml and was higher than the permitted limit according to Regulation (EC) No. 853/2004 of the European Parliament and the Council. In contrast to a study by Gulbe and Valdowska [2014], no significant differences were found between the seasons analysed (Table 1). It should be emphasised that raw milk is often used to produce regional cheese in home-based processing plants. Moreover, milk bought straight from the farm is usually considered to be very fresh, safe and healthier than milk purchased in the food store; thus often it is consumed raw. The results of TBC suggest that the hygienic quality of milk in SFFs can be an issue and that milk used in the production of milk products should be subjected to pasteurisation. It should be stressed that cheese made from raw milk may contain pathogenic bacteria, e.g. *Listeria monocytogenes*, *Salmonella*, *Escherichia coli*, *Campylobacter*, *Yersinia*.

A higher somatic cell count was found in the milk collected in the autumn-winter season compared with the milk collected in the spring-summer season (P ≤ 0.05; Table 1), which is consistent with the results of a study by Rajèeviè et al. [2003] on milk from black and white cows in Slovenia. The somatic cell count in healthy cows' milk should not be higher than 100,000 per ml of milk [Sharma et al. 2011]. In turn, in accordance with Regulation (EC), No. 853/2004 of the European Parliament and the Council, the somatic cell count of raw milk must not exceed 400,000 per ml. The higher SCC observed in our study in the indoor season may result from a change in the diet of the animals, their welfare conditions, confirmed cases of mastitis, drying-off as well as calving season. Moreover, the difficult conditions of keeping cows in the barn, related to the tether system and deep litter, could have had a significant impact on the increase in SCC content in milk in winter. It should also be noted that the welfare conditions in barns where small herds are kept are often worse and the managers of such herds have lower qualifications. In contrast to the results presented, Alhussien and Dang [2018] found a higher SCC content in milk obtained in summer than in winter. This was associated not only with stress in animals in hot weather but also with reduced quality of pasture feed, which could have a negative impact on the animal's resistance and contribute to increased bacterial infections. Similarly, a study by Butler et al. [2010] found that the SCC in the milk collected in summer was 38% higher compared with the milk collected in winter. Own research has shown highly significant positive correlations between the SCC and the TBC, both in the autumn-winter season (r = 0.903**) and in the spring-summer season (r = 0.896**).

Somatic cell count of milk above the norm highlights that mastitis and milking hygiene are still a challenging task at SFFs. Mastitis is one of the most prevalent and costly diseases in the dairy cattle industry worldwide [Damm et al. 2017]. According to Irish studies management practices associated with low SCC include the use of dry cow therapy, participation in a milk recording scheme, the use of teat disinfection post-milking, a higher frequency of cleaning and increased farm hygiene. Management practices associated with low TBC included the use of heated water in the milking parlour, participation in a milk recording scheme, tail clipping of cows at a frequency greater than once per year and increased farm hygiene [O'Brien et al. 2009]. Thus, to gain more profit from milk production, SFFs should participate in milk recording scheme and apply to the above recommendations.

Moreover, for safety reasons, all products produced on the farm should be manufactured from pasteurised milk. It is commonly believed that the pasteurisation process not only inactivates the pathogenic microorganisms but also results in loss of nutrients. According to our unpublished studies and studies of Moltó-Puigmartí et al. [2011] fatty acid proportions in milk, as well as levels of delta-, gamma-, and alpha-tocopherols did not vary after pasteurisation process, while total vitamin C level decreased only by 8–20%. The highest losses of bioactive components in milk occur during storage and boiling [Markiewicz-Kęszycka et al. 2014, Khan et al. 2017]. This suggests that fresh milk purchased on the farm will provide higher biological value than its counterpart bought in the food store, however, its hygienic quality might be lower. More studies are needed on the safety and bioactive compounds of milk produced by small, extensive family farms which sell milk directly to the consumers.

CONCLUSION

The quality of milk from the studied extensive small family farm where cows are grazing in the summer season is significantly dependent on the feeding season. In the autumn-winter season, a higher somatic cell count, higher protein, fat and lactose levels, longer rennet coagulation time and lower colour parameter a* values were found compared with the spring-summer period. Milk collected in the autumn-winter season did not differ from that obtained in the spring-summer season in terms of the total bacterial count, colour parameters L* and b* and vitamin C content. It should be stressed that, in the overall period covered by the study, the milk had high vitamin C content (3.81 mg · 100 mL^{-1}) when compared to the milk purchased in the food store.

The results of this case study provide small family farmers producing milk with a better view of how important the quality parameters of milk are and contribute to optimum use of milk in home-based processing plants.

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SEZONOWE RÓŻNICE W PARAMETRACH JAKOŚCIOWYCH MLEKA Z TRADYCYJNEGO MAŁEGO GOSPODARSTWA RODZINNEGO

STRESZCZENIE

Celem badań było określenie jakości higienicznej, właściwości fizykochemicznych i przydatności technologicznej mleka pozyskanego w małym rodzinnym gospodarstwie rolnym w zachodniej Polsce w sezonie wiosenno-letnim (pastwisko) i sezonie jesienno-zimowym (obora). Gospodarstwo jest prowadzone w tradycyjny sposób; zwierzęta spędzają 24 godziny na dobę na pastwisku w sezonie wiosenno-letnim. Badanie przeprowadzono na 48 próbach zbiorczego mleka, pobieranego raz w tygodniu przez cały rok od 17 krów starej lokalnej polskiej rasy nizinnej czarno-białej. Mleko badano pod kątem liczby komórek somatycznych, całkowitej liczby bakterii, składu chemicznego, gęstości, zawartości witaminy C, czasu krzepnięcia pod wpływem podpuszczki, pH i barwy w układzie CIE L*a* b*. W sezonie jesienno-zimowym stwierdzono wyższą liczbę komórek somatycznych, wyższy poziom białka, tłuszczu i laktozy, dłuższy czas krzepnięcia mleka oraz niższe wartości parametru barwy a*, w porównaniu z okresem wiosenno-letnim. Nie zaobserwowano jednak różnic w zakresie parametrów barwy L* oraz b*, a także zawartości witaminy C między sezonami. Stwierdzono wysoko istotne ujemne korelacje między barwą mleka a całkowitą liczbą bakterii i liczbą komórek somatycznych ($P \leq 0.01$). Wysoka liczba komórek somatycznych w mleku wskazuje, że zapalenie wymienia oraz higiena doju krów są nadal problemem w małych gospodarstwach rodzinnych.

Słowa kluczowe: ekstensywna hodowla bydła, sezonowość, jakość higieniczna, barwa mleka, witamina C

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