Raw milk quality – Part 1. Dairy animals and milk hygiene

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Milk - definition

milk – a fluid secreted by the mammary glands of female mammals. generally consisted of 80-90% water, 10-20% dry matter (i.e. fat, proteins, lactose, mineral substances)

Dairy congress in Geneva (1914):

Milk – product of complete and continuous milking obtained in the proper way from healthy, well-nourished, not tired milk cow without colostrum*

* *Colostrum* is the first form of *milk* produced by the mammary glands of mammals (including humans) immediately following delivery of the newborn

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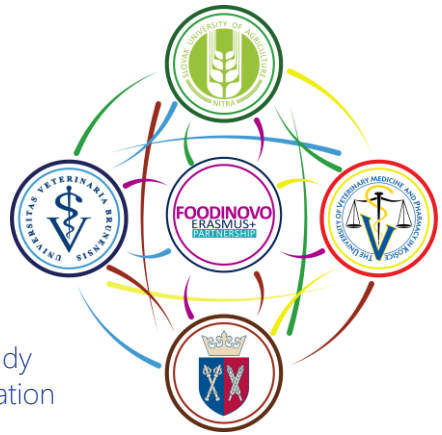
World production of milk from different animal species (FAOSTAT 2017)

Milk type	Production in mln tonnes	% in total production
Cow	674.49	81.58
Buffalo	120.35	14.56
Goat	18.66	2.26
Sheep	10.40	1.26
Camel	2.85	0.34
All types	**826.75**	**100**



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Aaverage composition of milk of selected animals and human [% w/w]

Species	Water	Dry matter	Fat	Protein	Lactose	Ash
Cow	87.0	13.0	4.2	3.3	4.7	0.7
Goat	86.8	13.2	4.5	2.9	4.1	0.8
Sheep	80.7	19.3	7.4	5.5	4.8	1.0
Horse	88.8	11.2	1.9	1.5	6.2	0.5
Buffalo	82.8	17.2	7.4	3.8	4.8	0.8
Camel	88.7	11.3	3.3	2.7	4.7	0.7
Human	87.6	12.4	3.8	1.0	7.0	0.2

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Dairy animals

- Cow (cattle)

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Dairy animals

- Goat

Main producers of goat milk (*also referred as caprine milk) : India (22%), Mediterranean countries (18%): Greece, Spain, France.

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Dairy animals

- Sheep

Sheep milk (*also referred as ewe'e or ovine milk) is popular in Spain, France, Poland.

** Oscypek (oszczypek) – popular regional cheese produced in Poland from sheep milk*

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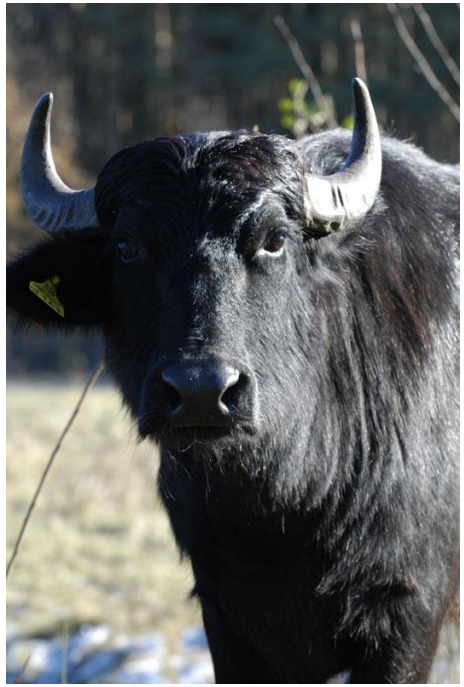
Dairy animals

- Buffalo

(Italy, India)



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Dairy animals

- Horse

Equine milk/ mare's milk (Mongolia, Bashkiria)

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Dairy animals

CAMEL
Africa, south-west Asia,
India, Pakistan, Mongolia

DONKEY
Serbia*

ELK (moose milk)
Sweden, Russia

** The most expensive cheese in the world is produced from donkey milk in Serbia. One kg of this cheese (called Pule) is produced from 25 litres of milk and it is worth approx.* $600.

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Dairy animals

Pig (Africa)

Reindeer (Lapland)

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Average composition of cow milk (%)

Component	Average	Variations
Water	87.1	85.3 – 88.7
Dry matter	12.9	11.3 – 14.7
Fat	4.0	2.5 – 5.5
Total protein	3.3	2.3 – 4.4
Lactose	4.6	3.8 – 5.3
Ash	0.7	0.6 – 0.8

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Milk composition, quality and yield – sources of variation (%)

- species, breed and individual (genetic factors)
- physiological
  - stage of lactation
  - number of lactation (age of the cow)
  - time intervals between milkings
- nutritional status (feeding mode)
- other environmental factors: climate, soil etc.
- health factors (mastitis and other diseases)

- milk production is seasonal*

* In a bulked factory milk supply, variability due to many of these factors is evened out, but some variability persists and may be quite large because milk production is seasonal

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Milk composition of the selected cows breeds (%)

Breed	Water	Fat	Total protein	Lactose	Ash	Non-fat dry matter
Guernsey	85.35	5.05	3.90	4.96	0.74	9.60
Jersey	85.47	5.05	3.78	5.00	0.70	9.48
Ayrshire	86.97	4.03	3.51	4.81	0.68	9.00
Brown Swiss	86.87	3.85	3.48	5.08	0.72	9.28
Shorthorn	87.43	3.65	3.32	4.89	0.73	8.94
Holstein-Friesian	87.72	3.41	3.32	4.87	0.68	8.87

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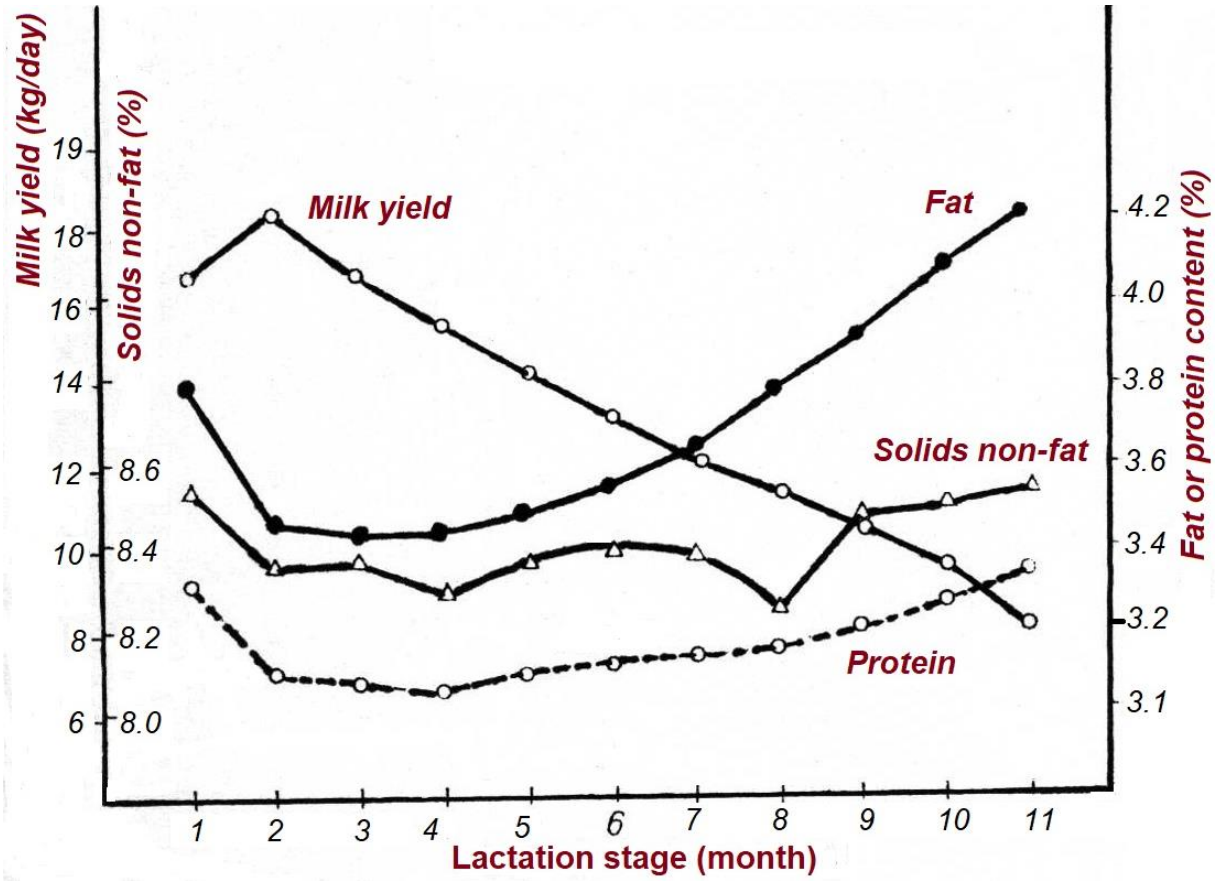
Changes of milk composition during lactation



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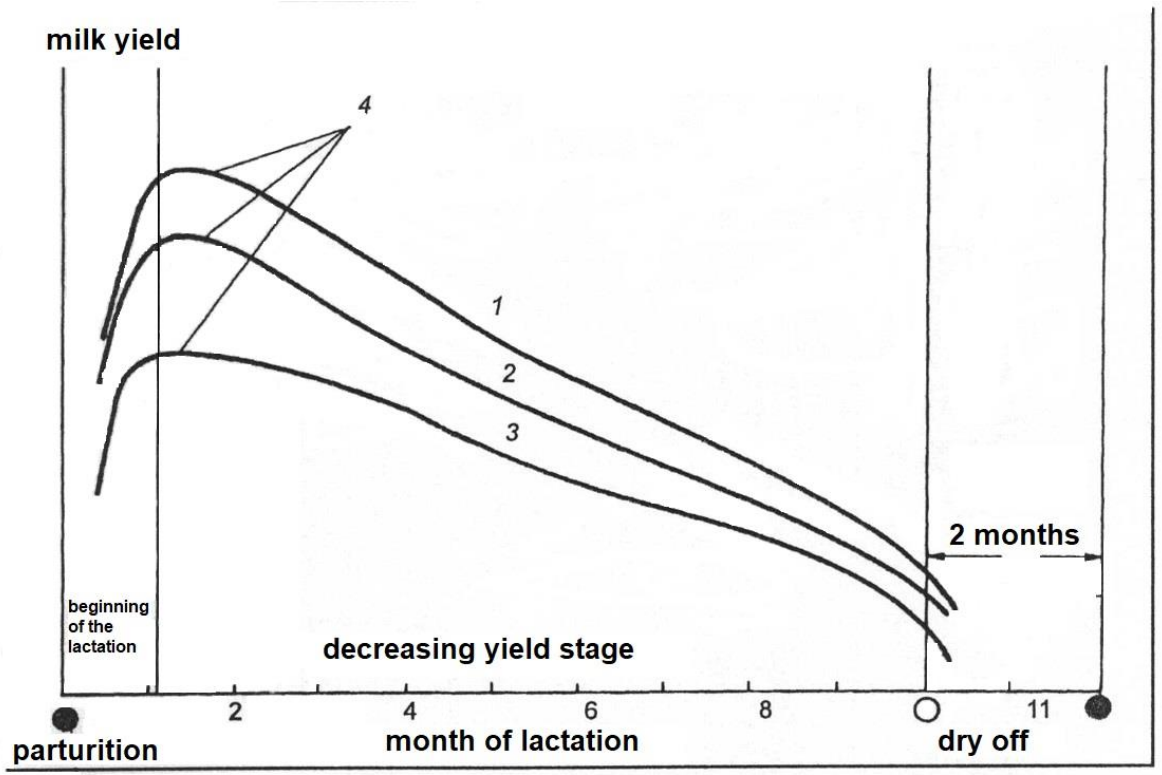
Changes of milk yield between subsequent lactations – lactation curve



Model curves of lactation: 1 - third lactation, 2 - second lactation, 3 - first lactation, 4 - peak of lactation (Charron 1986)

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Impact of feeding on milk composition

- forage maintenance requirements: 7500 kJ/100 kg bodyweight;
- forage requirements for milk production: 3100 kJ/1 l milk (4% fat)
- proper content of proteins, minerals and vitamins;
- constant access to water : 3-4 l water per 1 litre of produced milk;
- supplementation of daily feeding rations with salt;
- influence of fibre content in forages on the fat content in milk;
- higher fat content in milk increases demand for protein in forage;
- low protein content in forage – low casein concentration in milk (low effectiveness of modification)
- avoid rotten, mouldy, musty forages – impact on milk composition and aroma

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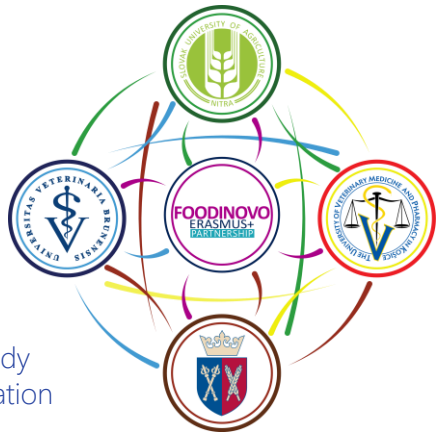
Impact of feeding on milk sensory properties

Taste and odour of some forages negatively affects the taste and aroma of milk, e.g.:

- harsh, unpleasant taste and aroma gives wormwood and garlic,
- swede, turnip and rapeseed cake – confer bitter taste to milk,
- fishy taste and aroma – beetroots and beet leaves, - cabbage taste and aroma – swede and cabbage,
- silages – contamination with coliform bacteria and butyric bacteria.



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Hygiene of raw milk - legislation

- REGULATION (EC) no 852/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 April 2004 on the hygiene of foodstuffs *(Annex I concerning general hygiene provisions for primary production and associated operations)*

- REGULATION (EC) No 853/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 April 2004 laying down specific hygiene rules for on the hygiene of foodstuffs *(Annex III. Specific requirements, Section IX: Raw milk and dairy products, Chapter I: Raw milk-primary production) with subsequent changes (Reg. no 1662/2006)*

- Regulation of the Ministry of Agriculture and Rural Development of 18 August 2004 on veterinary requirements for milk and dairy products *(The Official Journal, no. 188, Item 1946 with further changes)*

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Hygiene of raw milk production

- cowshed hygiene;
- management and maintenance of animals (cows);
- disease prevention and combating;
- hygiene of milking;
- milk management after milking.

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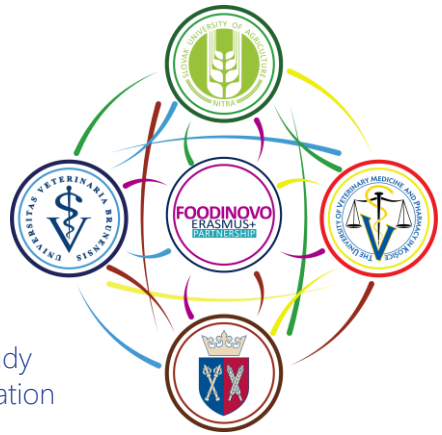
Protection against diseases and disease control

- constant veterinary care
- the most dangerous cow diseases:
  - tuberculosis – bad hygienic conditions,
  - brucellosis – contagious abortion (*Brucella abortus*),
  - foot-and-mouth disease (bluetongue disease) – disease of mouth and hoovers (viral),
  - leukaemia,
  - mammary gland infection (mastitis).



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Udder infections (mastitis)

Inflammations:

- acute – visible symptoms – redness, fever, swelling of the teat;
- latent – subclinical – chronic – difficult to recognize – without visible symptoms

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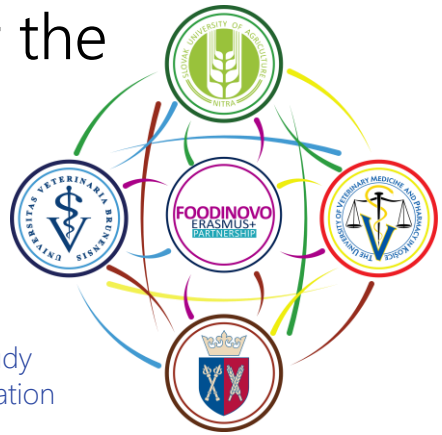
Udder infections (mastitis)

Reasons:

- bacterial infections (pyogenic staphylococci and streprococci – *Staph. aureus*, *Str. agalactiae.*, *Str. dysagalactiae*);
- abnormalities (defects) in the udder structure;
- mechanical damages (sores) of teats during milking (overmilking);
- teat muscle weakness;
- defects of milking machine (‘reverse flow’ or the ‘impact’ of milk droplets during milking);
- inaccurate milking.



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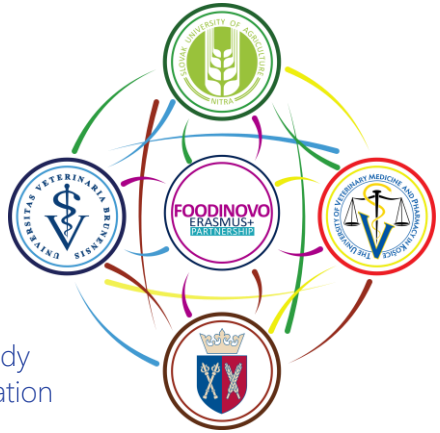
Udder infections (mastitis)

Changes in milk:

- decreased content of dry matter, fat, calcium, potassium, phosphates;
- significant decrease of the lactose content;
- significant increase (even 5-fold) of the whey protein content;
- high level of leucocytes;
- significant increase of the chloride content.



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Udder infections (mastitis)

Detection:

- California Mastitis Test (diagnostic liquids e.g. Mastirapid)
- Whiteside test
- Chloride/lactose ratio = $\frac{\% \text{ chlorides}}{\% \text{ lactose}} \times 100$

  - milk from healthy cows -1.5 - 3.0
  - increased (~5-6) – milk from cows with mastitis symptoms

- Increased content of catalase – catalase test
- Automated cell counters (e.g. Fossomatic)
- Detectors that measure changes in the electrical resistance of milk

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Hygiene of milking

Hygienic conditions:

- cowshed should be cleaned 1hour before milking
- hygiene of the milkers (operators performing milking and/or handling raw milk)
- all equipment, containers used for milk should be kept clean
- cleaning, disinfection, wiping and teat massage,
- pre-milking
- milking (hand milking or application of the machine)
- post-milking massage
- disinfection of teats

Types of milking:

- manual
- mechanical – bucket milking machine
- mechanical - pipeline milking machine

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Quality of raw milk

Characteristics of raw milk quality:

- chemical composition;
- physical properties;
- microbiological quality;
- cytological quality;
- sensory properties;
- nutritional value;
- chemical contamination.

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Quality of raw milk

REGULATION (EC) NO 853/2004 OF THE EUROPEAN PARLIAMENT AND THE COUNCIL OF 29 APRIL 2004, LAYING DOWN SPECIFIC HYGIENE RULES FOR FOOD OF ANIMAL ORIGIN:

- „raw milk" – milk derived from mammary glands of farmed healthy animals that has not been heated to more than 40 °c or undergone any other treatment that has an equivalent effect.

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Regulation (EC) No 853/2004 - requirements

I. Health requirements

1. Animals - in a good general state of health that do not show any symptoms of infectious diseases communicable to humans and without any udder wound likely to affect the milk.
2. Animals - to which no unauthorized substances or products have been administered and that have not undergone illegal treatment.
3. Animals - in respect of which, where authorized products or substances have been administered the respective for these substances withdrawal periods have been observed.

II. Hygiene on milk production holdings

a. Requirements regarding premises (where milk is stored, handled or cooled), equipment and utensils

b. Hygiene during milking, collection and transport Immediately after milking milk must be cooled to the temperature not exceeding 8 °C in the case of daily collection, or not more than 6 °C if collection is not daily.

Transport – the temperature of the milk on the arrival to the destination place not higher than 10 °C.

In special circumstances if the milk meets the microbiological criteria it must not be cooled down:

- if it is processed within 2 hours after milking;
- from technological reasons related to the manufacture of certain dairy products but with the permission of the respective authority.

c. Staff hygiene requirements – suitable clean clothes, washing facilities, high degree of personal cleanliness

III. Criteria for raw milk

Cows' milk:	Not more than:	Frequency of testing:
Plate count of microorganisms at 30 °C in 1 mL of milk	100 000	Geometric average over a 2-month period, with at least two samples per month.
Somatic cell count per 1 mL of milk	400 000	Geometric average over a 3-month period, with at least one sample per month.

Other criteria: milk must not contain antibiotic residues (exceeding the permitted level)

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Raw milk microbiota

- Saprophytic microorganisms:
  - lactic acid bacteria;
  - coliform bacteria: *Enterobacter*, *Escherichia*, *Klebsiella* (indicator of the sanitary and hygiene conditions of the milk production)
  - intestinal enterococci (*Enterococcus*);
  - heat-resistant bacteria: *Microbacterium*, *Micrococcus*, *Bacillus*;
  - psychrotrophic bacteria and psychrophilic bacteria: *Pseudomonas*, *Alcaligenes*, *Flavobacterium*, *Aeromonas genera*
  - proteolytic bacteria: *Pseudomonas*, *Proteus*, *Bacillus*
  - lipolytic bacteria
  - spore-forming bacteria: *Bacillus*, *Clostridium*
  - molds, yeasts, Actinomycetes

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Raw milk microbiota

- Pathogenic bacteria:
  - tubercular bacilli: *Mycobacterium tuberculosis, M. bovis;*
  - *Brucella abortus;*
  - staphylococci: *Staphylococcus aureus, Str. agalactiae, Str. dysagalactiae;*
  - *gut (enteric) bacteria: Salmonella, Shigella, Yersinia, E. coli;*
  - *Clostridium botulinum, Clostridium perfringens,*
  - anthrax: *Bacillus anthracis;*
- Viruses

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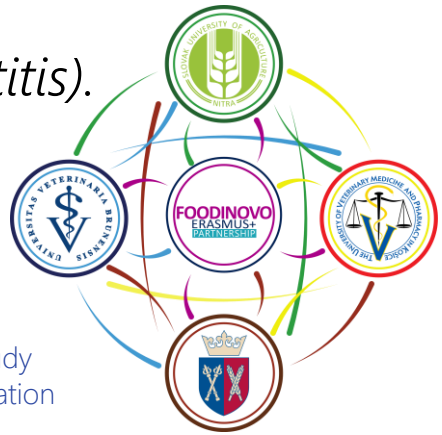
Somatic cells

- Cells coming from the mammary gland (whole or damaged)
  - cells from epithelium of alveoli, milk capillaries, ducts and cistern of the udder
- Cells from blood and lymph:
  - leucocytes (granulocytes and agranulocytes: lymphocytes and monocytes);
  - erythrocytes (occasionally)
  - colostrum cells

- During udder inflammation increased number of somatic cells (mainly leucocytes) is observed:
  - *above 500 000 in subclinical mastitis;*
  - *even to tens of millions in acute infection (clinical mastitis).*



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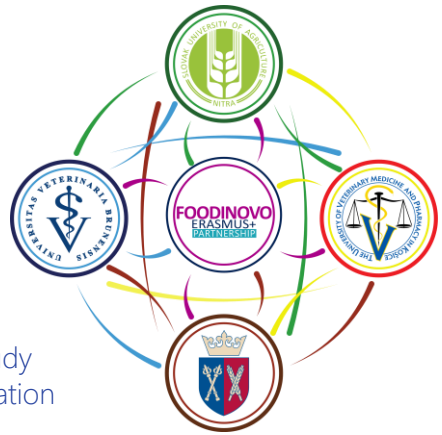
Chemical contamination of milk

- Heavy metals: Pb, Hg and Cd
- Pesticides
- Nitrates and nitrites
- Traces of antibiotics or cleaning agents and disinfectants
- polychlorinated biphenyls
- Dioxins
- Aflatoxins and their precursors
- Radionuclides: ^{40}K, ^{89}Sr, ^{90}Sr, ^{131}I, ^{137}Cs



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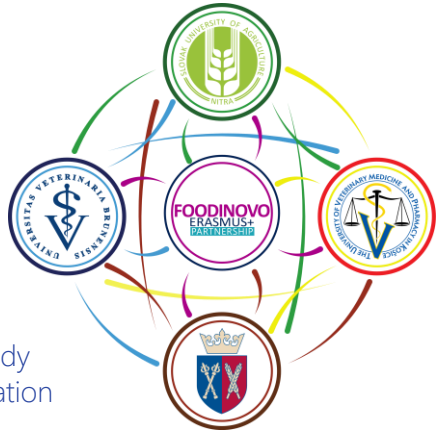
Raw milk purchase requirements

Milk must come from healthy animals (cows), without either addition to it or extraction from it.

It is forbidden to deliver milk:

- from diseased cattle and during medicinal treatment (and before the end of the withdrawal period established for used medicine);
- with abnormal (changed) organoleptic features;
- not later than 3 weeks before calving (drying off) and not earlier than 6 days after calving (colostrum);
- adulterated;
- in case of reception ban established by official veterinarian.



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Polish Standard PN-A-86002: 2002. Raw milk for sale. Requirements and tests.

Required milk parameters for all milk batches:

- appearance – color white with cream-colored shade, without visible mechanical contaminants;
- smell – specific to milk, without foreign odour;
- temperature – ≤ 8 ºC (daily reception), ≤ 6 ºC (other reception), not-cooled (reception up to 2 hours after milking).
- acidity – measure of milk freshness:
  - titratable acidity – 6.0-7.5 ºSH;
  - pH – 6.6-6.8

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Polish Standard PN-A-86002: 2002. Raw milk for sale. Requirements and tests.

Detailed milk requirements:

- density – not lower than 1.028 g/ml;
- freezing point – not higher than -0.520 °C;
- antimicrobial substances (antibiotics, cleaning agents etc.) – not accepted.

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Analyses of raw milk

Methods of milk assessment for health state of mammary gland (mastitis):

- instrumental methods (e.g., Fossomatic apparatus)
- microscopic methods according to PN-EN ISO 13366-1
- indirect methods:
  - Whiteside test
  - test with Mastirapid® (California Milk Test)

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Analyses of raw milk

Methods of assessment of milk microbiological quality

- instrumental methods – e.g. Bactoscan,
- one-use tests e.g. Petrifilms
- plate count method (Koch method)

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Analyses of raw milk

<u>Analyses for basic chemical composition of milk:</u>

A. Fat content:
- Röőse-Gottlieb method;
- Gerber method.

B. Protein and casein content:
- Kjeldahl method;
- Walker method.

C. Lactose content:
- Bertrand method;
- Polarimetric method;
- Enzymatic tests.

D. Ash content
- Incineration in a muffle furnace at 550 °C

E. Infrared method (e.g. MilcoScan)

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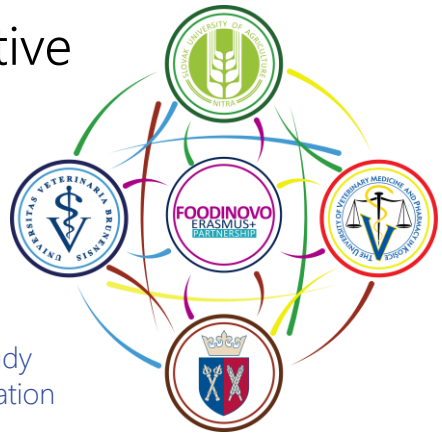
Milk technological suitability

I. For the production of milk concentrates:

High thermal stability (resistance to high temperatures without changes in physicochemical properties)

a. Direct tests
    a. Thermal coagulation at 140°C – min. 10 minutes
b. Indirect tests:
    a. Alcohol number - above 6
    b. Alcohol titre – min. 75%
    c. Single alcohol test and double-alcohol test - negative



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Milk technological suitability

II. For cheese production:

- fresh milk with normal composition
- titratable acidity 6-7.5°SH
- pH 6.6 –6.8
- TMC (Total Microorganisms Count)* - not to exceed 100 000 cfu/cm^3
- somatic cell count - not to exceed 400 000/cm^3
- fermentation test: J (jelly), W1-3 (wheyey), G1 (granular)
- fermentation test with added rennet: I and II type
- rennet-induced coagulation test: 4-10 min.
- detection of spore forming bacteria: not present

** Total viable count of bacteria, yeast, mould, spores*

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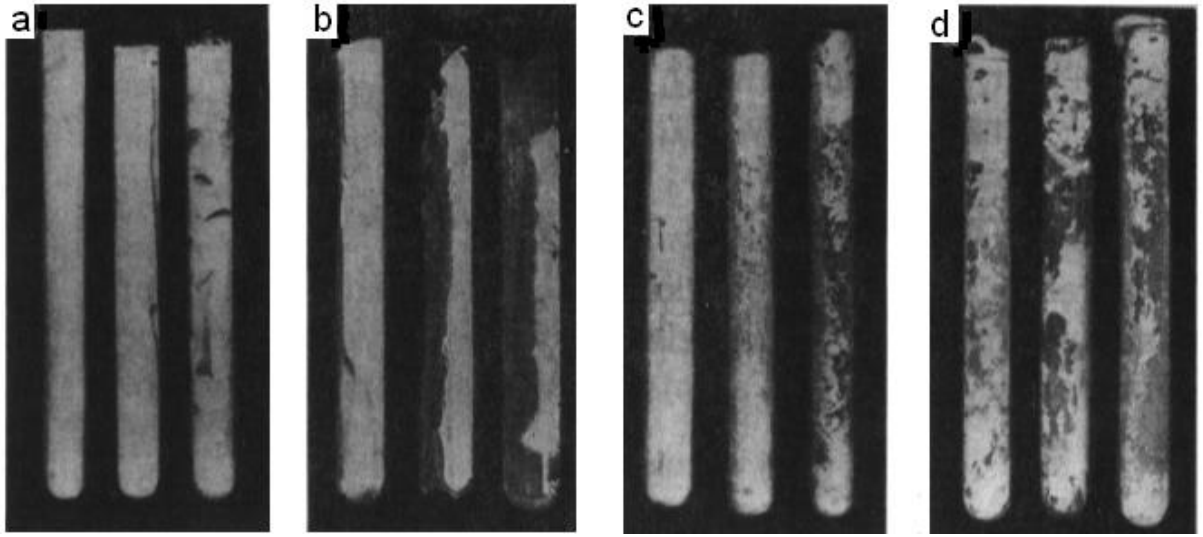
Milk technological suitability

II. For cheese production:

Fermentation test: types of curds:



a) Jelly (J) b) Wheyey (W) c) Granular (G) d) Swelly (S)

Other possible results:
-liquid milk (coagula not formed)

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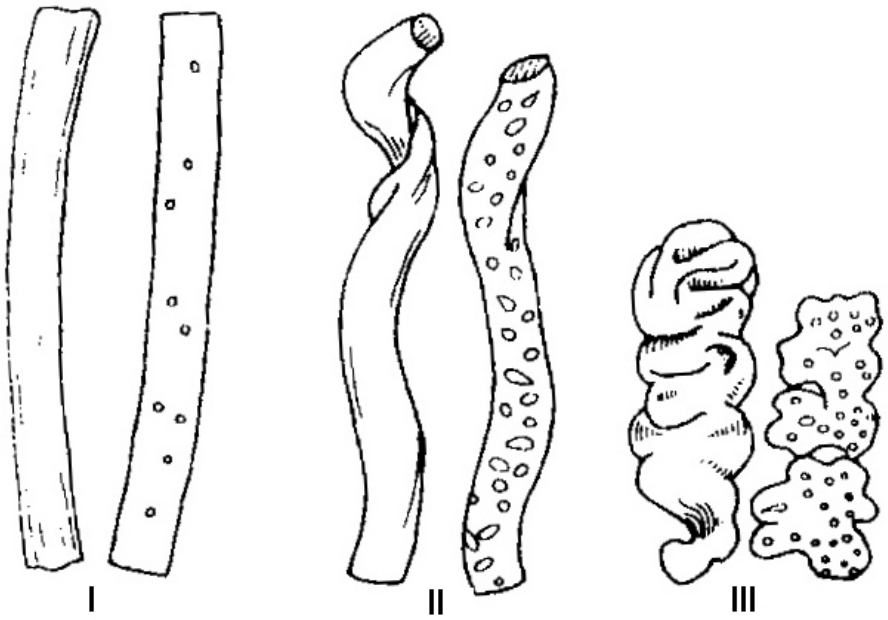
Milk technological suitability

II. For cheese production:

Fermentation test with added rennet: types of curds:



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Thank you for your attention

Dr hab. inż. Dorota Najgebauer-Lejko, prof. URK
Department of Animal Product Technology
Faculty of Food Technology
e-mail: dorota.najgebauer-lejko@urk.edu.pl
phone: 4812 662 4805

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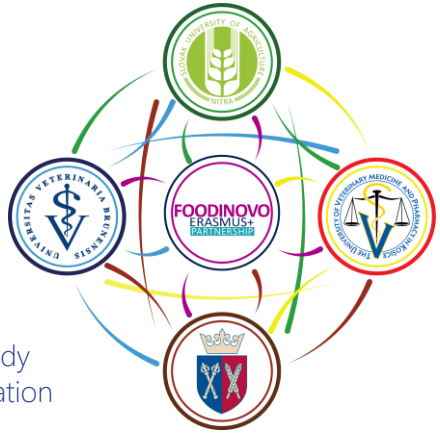

This work was co-funded by the Erasmus+ Programme of the European Union

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Inovácia štruktúry a obsahového zamerania študijných programov profilujúcich potravinárske študijné odbory s ohľadom na digitalizáciu výučby

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