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PLANT MODIFIERS OF COAGULATION AND PROTEIN RETENTION IN MIXTURES OF COW AND CAMEL MILK

Abstract: *The aim of this review is to analyse the mechanisms of plant extract action on milk coagulation and to evaluate their applicability in mixtures of cow and camel milk. The review includes publications devoted to the milk-clotting activity of plant proteases, the influence of polyphenolic compounds on casein micelle aggregation, and the role of technological parameters in the coagulation process.*

The analysis shows that plant extracts can act through two main mechanisms. The first mechanism is associated with proteolytic hydrolysis of κ-casein and the initiation of micelle aggregation. The second *mechanism is related to interactions of polyphenols and pectic substances with proteins, which modifies interparticle interactions and the water-holding capacity of the gel. The efficiency of extracts depends on their composition, concentration, pH of the medium, temperature, and calcium content.*

However, plant proteases often have lower selectivity compared to chymosin. This may lead to excessive proteolysis and weakening of the curd structure. In mixtures of cow and camel milk, additional factors are related to differences in protein composition and colloidal stability of the milk systems.

The review confirms the potential of plant-based modifiers of milk coagulation. At the same time, it highlights the need for careful optimization of technological conditions and a mechanistic approach to their application. For practical implementation, further studies are required to evaluate gel microstructure, protein retention, and the balance between milk-clotting and proteolytic activities.

Key words: *casein, κ-casein, mixtures, extracts, gelation, syneresis, curd, stability.*

Introduction

Milk coagulation is the process of protein clot formation. It is based on the destabilization of casein micelles and their subsequent aggregation. In cow's milk, this mechanism has been well studied. It involves the breakdown of κ-casein and the formation of a three-dimensional protein network with the participation of calcium [1].

Camel milk differs in composition and structure. It has a lower κ-casein content. The micelles are larger. The mineral balance differs from cow's milk. As a result, coagulation is slower. The resulting curd is less dense. Protein loss into whey may be higher [2].

When cow and camel milk are mixed, their properties do not average out. A heterogeneous system is formed. It contains different types of micelles. They have different surfaces and varying sensitivities to pH and calcium. This leads to uneven aggregation. The gel network becomes non-uniform, with zones of weakness forming within it [3].

This structure may explain the reduced yield of curd in mixtures. Protein losses are not due to a protein deficiency, but to the specific properties of the spatial network.

Plant extracts are considered as potential modifiers of these processes. They contain polyphenols, pectin substances, and organic acids. These components can alter micelle interactions and influence the rate of aggregation and gel density.

However, most studies are applied in nature, assessing yield and texture. The mechanisms of interaction are poorly described.

Therefore, a systemic analysis is needed. The influence of plant components should be examined from the perspective of colloidal chemistry and protein network structure.

The aim of this review is to analyze the mechanisms by which plant extracts influence coagulation and protein retention in cow and camel milk mixtures. A conceptual model explaining the possible compensatory effect of such modifiers is also proposed.

Literature Review

Characteristics of the camel milk protein system and their relationship to coagulation

In the literature, camel milk is described as having a casein micelle structure distinct from that of cow's milk. The low proportion of κ-casein is often emphasized. κ-casein is important for stabilizing micelles and also determines the efficiency of enzymatic coagulation. Without it, micelles have poorer control over aggregation. Therefore, the gel is weaker and more porous [4].

Many authors also note the larger micelles in camel milk. Large micelles can form a network with large pores. This facilitates whey drainage but also increases the risk of protein loss and reduced curd yield [5].

A separate block of research is devoted to the role of mineral balance in milk coagulation. Calcium ions participate in the binding of casein particles and strengthen intermicellar contacts. Changes in the content of micellar calcium phosphate and pH significantly affect the aggregation of casein micelles and the structure of the forming gel [6]. For camel milk, features of micelle mineralization and calcium distribution are described, which can alter the sensitivity of the protein system to Ca^{2+} and pH. As a result, the same concentration of $CaCl_2$ can have different effects in cow's and camel's milk.

Some publications discuss the composition of whey proteins. Camel milk lacks β-lactoglobulin. This alters thermal denaturation and subsequent interactions with caseins. Therefore, the system's behavior during heating and acid coagulation may differ from that of cow's milk.

The main conclusion of this line of research is simple. The difficulties in coagulating camel milk are related to its basic micellar architecture. These limitations cannot be completely eliminated by technological modifications alone. The aggregation pathway or network structure must be altered.

Coagulation in mixtures of cow and camel milk.

Studies on mixtures typically show improved coagulation with increasing cow's milk content. However, the improvement is often nonlinear. This is because the mixture becomes a heterogeneous system. It contains two types of micelles simultaneously. They have different surface properties and different sensitivities to calcium and pH. Therefore, aggregation can occur asynchronously.

Some studies note that the mixture produces a gel, but the curd yield remains lower than that of pure cow's milk. This is explained by the poor integration of camel micelles into the overall network. As a result, the network is non-uniform, with «weak zones» appearing. These zones facilitate whey release, which reduces protein retention [4].

It's important to note that there's a discrepancy in the literature between the «gel strength» and «yield» parameters. Sometimes, yield can be higher with a looser gel. This occurs due to water retention. Therefore, comparisons between studies are often inaccurate. Different authors measure different endpoints. Some evaluate yield. Others evaluate texture. Still others evaluate syneresis. This creates a perception of «contradictions», although in fact, the evaluation criteria vary [7-10].

Another source of discrepancies is the coagulation method. Mixtures employ acid coagulation, enzymatic coagulation, or a combined approach. These mechanisms produce different types of networks. They also respond differently to plant components.

Plant modifiers: general composition and principle of action

Plant extracts typically contain several classes of compounds. These include polyphenols, polysaccharides (including pectins), and organic acids. Proteases are sometimes present. Therefore, a single extract can act through several mechanisms simultaneously [11].

The literature often uses the term «natural coagulants». However, mechanistically, it is important to distinguish two cases. The first is when the extract acts as an enzyme source. This is similar to a Rennet-like pathway. The second is when the extract acts as a colloid modifier. In this case, it alters the charge, hydrophobicity, and interactions of micelles. These two cases can produce the same visual result (a coagulant), but different structures and different quality [8].

Polyphenols: bridging aggregation and precipitation risk

Polyphenols bind to proteins through hydrogen bonds and hydrophobic interactions. Caseins are particularly sensitive to polyphenols. This is due to their open structure. At moderate concentrations, polyphenols can enhance aggregation. They can act as «bridges» between particles, increasing the network density. This may improve protein retention [12].

However, the literature also notes a reverse effect. At high polyphenol concentrations, independent coagulation of protein-polyphenol complexes is possible. This leads to the formation of aggregates that do not integrate into the continuous gel network. This deteriorates the structure. This can increase turbidity. This can impair flavor due to astringency [13-15].

There is another important aspect. Protein-polyphenol complexes can alter protein digestibility. Some studies show a decrease in the rate of proteolysis [16, 17].

Therefore, technological gains can be accompanied by nutritional tradeoffs. This issue is rarely considered in applied studies.

Pectins can influence coagulation in several ways. At neutral pH, they can cause a depletion effect. This increases the effective attraction of particles, accelerating flocculation [18]. However, it can also increase heterogeneity. In acidic coagulation, the role of electrostatics and calcium increases. Pectin can form complexes with casein [19].

This increases water-holding capacity. This can reduce syneresis. Contradictions in the literature often arise from the different types of pectin. The degree of esterification is important. The molecular distribution is important. The calcium concentration is important. The rate at which the pH drops is important [20, 21].

Therefore, the same component can either improve the gel or destroy its structure. This is the «narrow process window».

Ionic factor: $CaCl_2$, phosphates and buffer capacity

Adding $CaCl_2$ typically accelerates coagulation and strengthens the network. This is due to the strengthening of bonds between casein particles. However, excess calcium can increase syneresis, making the network more rigid and prone to drainage [22].

The role of phosphates is also discussed in publications. They can bind calcium and alter the availability of ions. Therefore, the effect of $CaCl_2$ depends on the initial mineralization of the milk and on the additives [23-25].

In cow and camel milk mixtures, ionic balance is particularly important. This is due to the different "tuning" of the micelles in each milk. Therefore, the same additives produce different results at different mixing ratios.

Plant extracts are typically low in protein. They can only influence the amino acid profile indirectly. This indirect effect is related to the retention of different protein fractions. If the protein chain retains more whey proteins, the relative distribution of amino acids changes. However, this does not mean a true enrichment of the limiting amino acid. To truly improve the amino acid profile, protein ingredients are needed, such as isolates or hydrolysates.

Review Methods

To analyze the effect of plant extracts on milk coagulation, the authors used publications obtained from international scientific databases, including PubMed, ScienceDirect, Food Chemistry, and other high-impact journals. The review included both experimental studies and comparative and mechanistic papers on plant coagulants and their properties. Inclusion criteria included data on the milk-coagulating activity of plant extracts, descriptions of the mechanisms of interaction with the milk protein system, measurements of rennin-like activity, or changes in the structural properties of the clot.

Data evaluation methods included the following parameters:

– Milk coagulation activity (MCA) over various pH and temperature ranges;

– Milk coagulation activity/proteolytic activity (MCA/PA) ratio;

– The effect of extracts on the structural characteristics of the resulting gel (texture, viscosity modulus, microstructure);

– Specific mechanisms of hydrolysis of casein fractions, including κ-casein;

– Comparative analysis with commercial coagulants (e.g., chymosin).

The studies were evaluated in terms of the use of plant extracts as an alternative to animal or microbial coagulants, as well as their impact on the technological properties of milk and solid milk products.

Review results

4. Results

The analysis of published studies showed that plant extracts influence milk coagulation through different mechanisms, including enzymatic, colloidal, and ionic interactions. Their effect depends on the type of active compounds and the composition of the milk system. To better understand their applicability in cow and camel milk mixtures, the results were grouped according to the main classes of modifiers.

4.1 Plant proteases

Plant proteases are the most studied group of plant milk coagulants. Their action is similar to animal rennet because they hydrolyse κ-casein and initiate aggregation of casein micelles. However, unlike chymosin, most plant proteases are less selective.

Chymosin specifically cleaves the Phe105–Met106 bond of κ-casein. Plant proteases can also hydrolyse κ-casein, but they often continue degrading other casein fractions such as αs1-, αs2-, and β-caseins after coagulation has already started. As a result, the formed gel becomes softer, protein losses into whey increase, and the MCA/PA ratio decreases compared to chymosin [28].

This does not mean that plant proteases cannot be used in dairy systems. However, their application requires more precise control of technological conditions.

Among the studied plant sources, pumpkin seed peptidases (Cucurbita moschata) demonstrated one of the widest activity ranges (pH 4.5-8.5; 20-80°C) and formed gels with high elastic modulus G′ [11]. Kiwi extract containing actinidin produced curd with texture similar to chymosin-induced gels at approximately 40°C [9]. Artichoke flower extract (Cynara scolymus) showed stable proteolytic activity and provided curd yields up to 17% in mini-cheese systems at pH 6.4 and 37°C [26].

At the same time, melon and Solanum elaeagnifolium extracts demonstrated lower MCA/PA ratios and produced looser gels because of extensive non-selective proteolysis [9, 27]. Therefore, their use as independent coagulants may be limited. Table 1 presents the comparative characteristics of the main plant milk coagulants.

Table 1 – Comparative characteristics of plant milk coagulants

Plant / source	Active component	Opt. pH	Temp., °C	MCA/PA	Curd characteristics	Ref.
Artichoke (Cynara scolymus L.)	Phenolic/protease extract (lyophilisate)	6.4	37-45	Moderate	Yield up to 17% (mini-cheese); stable proteolytic activity	[26]
Pumpkin (Cucurbita moschata)	Seed peptidases	4.5-8.5	20-80	High	Strong gel; high elastic modulus G′; wide working range	[11]
Kiwi (Actinidia sp.)	Actinidin (cysteine protease)	n/d	~40	Moderate	Curd texture comparable to chymosin; narrow temperature range	[9]
Melon (Cucumis melo)	Pulp proteases	n/d	45-75	Moderate	Loose curd; lower yield; wide temperature range	[9]
Ginger (Zingiber officinale)	Zingibain (cysteine protease)	n/d	~63	Moderate	Narrow optimum; activity at high temperature	[9]
Tompillo (Solanum elaeagnifolium)	Aspartate protease from fruits	n/d	n/d	Low	Slow coagulation; less dense gel; extensive non-selective proteolysis	[27]
Chymosin (control)	Aspartate protease (animal origin)	6.0-6.6	30-37	High	Reference: dense curd, high selectivity for κ-casein	[28]

Note: MCA/PA – milk-clotting to proteolytic activity ratio; n/d – no data; G′ – storage modulus of gel

An important observation from the literature is that practical applicability depends not only on coagulation time, but also on the MCA/PA ratio. Rapid coagulation combined with excessive proteolytic activity may lead to high protein losses and deterioration of curd texture during storage and ripening. However, this parameter is not reported consistently in many studies, which complicates direct comparison between different plant coagulants.

4.2 Polyphenols

Polyphenols affect milk coagulation through mechanisms different from proteases. They do not hydrolyse κ-casein. Instead, they interact with casein proteins through hydrogen bonds and hydrophobic interactions [14].

At moderate concentrations, polyphenols may act as bridges between casein micelles. This increases interparticle attraction and promotes formation of a denser gel network. As a result, protein retention may improve even without enzymatic activity.

However, the positive effect is observed only within a limited concentration range. At high concentrations, protein-polyphenol complexes precipitate independently from the continuous gel network. This leads to formation of isolated aggregates, increased turbidity, syneresis, and defects in gel structure [13-15].

Another important aspect is the effect of polyphenols on protein digestibility. Several studies reported that stable protein-polyphenol complexes are more resistant to proteolysis, which may reduce protein bioavailability [16, 17]. Therefore, improvement of texture may be accompanied by nutritional limitations. The concentration-dependent effects of polyphenols are summarised in Table 2.

In cow and camel milk mixtures, the effect of polyphenols may become more complex because the two micelle populations have different surface properties. Camel milk micelles are larger and contain less κ-casein, which may influence their interaction with polyphenols differently compared to cow milk micelles. At present, this mechanism remains poorly studied.

Table 2 – Concentration-dependent effects of polyphenols on milk gel structure

Polyphenol concentration	Effect on casein micelles	Gel/curd outcome	Ref.
Moderate	Hydrogen bonding and hydrophobic interactions with open casein structure; bridging between particles	Increased network density; improved protein retention	[12, 14]
High	Independent coagulation of protein-polyphenol complexes outside the gel network	Fragmented gel structure; increased turbidity; astringent off-flavour	[13-15]
Any level	Formation of stable protein-polyphenol complexes resistant to proteolysis	Reduced digestibility of retained proteins – nutritional tradeoff	[16, 17]

4.3 Pectins

Pectin itself is not a direct milk coagulant. Its main role is associated with modification of the colloidal environment around casein micelles. Depending on pH, ionic strength, and degree of esterification, pectin may either stabilise or destabilise the system.

At neutral pH, high-molecular-weight pectin promotes depletion interactions between micelles, increasing effective attraction and accelerating flocculation [18]. However, this may also increase heterogeneity of mixed milk systems.

Under acidic conditions, the mechanism changes. Low-esterified pectins can interact with casein micelles through calcium bridges [19]. This interaction improves water-holding capacity and reduces syneresis, which may increase curd yield.

Differences reported in the literature are mainly associated with variations in pectin structure, degree of esterification, molecular weight distribution, calcium concentration, and acidification rate [20, 21]. Since these parameters are not always described in publications, comparison between studies is often difficult. The main effects of pectin under different conditions are presented in Table 3.

Table 3 – Pectin effects on milk gel depending on pH and esterification degree

Condition	Mechanism	Effect on gel	Key variables
Neutral pH	Depletion interaction – increased effective attraction between micelles	Accelerated flocculation; risk of heterogeneous network	Pectin MW, concentration
Acidic pH, high esterification	Limited casein-pectin electrostatic interaction	Minimal influence on coagulation rate	Degree of esterification, pH drop rate
Acidic pH, low esterification	Casein–pectin complex formation via Ca^{2+} bridges	Increased water-holding capacity; reduced syneresis	Ca^{2+} concentration, esterification degree

Note: MW – molecular weight; Ca^{2+} – calcium ion concentration.

4.4 Ionic effects

Although calcium is not a plant modifier, it strongly influences the activity of plant coagulants because the ionic environment determines aggregation behaviour of casein micelles.

Addition of $CaCl_2$ strengthens intermicellar calcium phosphate bridges, accelerates aggregation, and increases gel firmness [22]. In cow milk systems, the optimal concentration range is relatively well established.

However, camel milk behaves differently. Camel milk micelles have another mineralisation pattern and respond differently to added calcium ions [6]. Therefore, the same $CaCl_2$ concentration may produce different effects depending on the ratio of cow and camel milk in the mixture.

Phosphates further complicate the system because they can bind free calcium ions and reduce their availability for intermicellar interactions [23, 24]. In addition, differences in buffer capacity between cow and camel milk influence pH reduction during acidification and affect aggregation kinetics.

These findings indicate that optimisation of ionic conditions in mixed milk systems cannot be directly transferred from single-milk systems. Separate optimisation is required for each milk ratio.

The main ionic effects observed in cow/camel milk mixtures are summarised in Table 4.

Table 4 – Ionic factors and their behaviour in cow/camel milk mixtures

Factor	Effect at optimal level	Effect when excessive / absent	Specific features in cow/camel mixture
$CaCl_2$	Strengthens inter-micellar bonds; accelerates aggregation	Excess (increased syneresis, overly rigid gel prone to drainage)	Same $CaCl_2$ dose acts differently at different mixing ratios due to distinct micelle mineralization
Inorganic phosphates	Modulate Ca^{2+} availability; buffer capacity adjustment	Sequester calcium (impaired aggregation)	Camel milk micelles have different micellar calcium phosphate content – complicates additive predictions
pH	Lowering pH reduces zeta-potential, promotes micelle approach and aggregation	Too low (acid-induced precipitation rather than structured gel formation)	Asynchronous pH sensitivity of two micelle populations – coagulation proceeds unevenly

4.5 Comparative analysis of plant modifier classes

The comparison of different modifier classes showed that plant proteases, polyphenols, pectins, and ionic factors do not act independently. Their effects may interact with each other within the milk system.

For example, extracts containing both proteases and polyphenols may simultaneously induce κ-casein hydrolysis and polyphenol-mediated interactions with casein proteins. Depending on process conditions, these effects may either improve or destabilise the gel structure.

In cow and camel milk mixtures, none of the modifier classes alone fully solves the problem of heterogeneous aggregation. Plant proteases initiate coagulation but cannot completely synchronise aggregation of structurally different micelles. Polyphenols may partially improve interactions between particles, whereas pectins mainly contribute to water retention and reduction of syneresis. Ionic adjustment is also necessary, but alone it is insufficient.

These observations suggest that combined approaches may be more promising than the use of a single modifier class. Combinations of plant proteases with moderate MCA/PA ratios and low-esterified pectins under controlled Ca^{2+} concentrations may improve both coagulation kinetics and structural stability of mixed milk gels. However, direct experimental validation of such systems remains limited. The comparative characteristics of the main modifier classes are presented in Table 5.

The overall analysis showed that effective optimisation of cow and camel milk mixtures requires consideration of multiple interacting factors rather than isolated technological parameters. Particular attention should be given not only to curd yield, but also to gel microstructure, protein retention, and stability of the formed network.

Discussion

The review data highlights that the activity of plant coagulants depends not only on their source but also on process parameters. Milk pH-lowering the pH accelerates coagulation for many plant extracts – is important. Process temperature-optimal activity ranges vary significantly between sources – is important. Enzyme concentration influences both coagulation time and curd texture. These parameters must be optimized for each plant coagulant and specific milk raw material.

Summary of the Effects of Plant Extracts

Overall, publications show that:

– Plant extracts can act as milk coagulants similar to rennet, but with broader proteolytic activity.

– They alter aggregation kinetics and gel structural characteristics through interaction with casein fractions.

– Their effectiveness and clot properties depend on the starting material, extract composition, and process conditions.

These data confirm that plant extracts are promising coagulation modifiers in dairy systems, but require precise optimization to achieve results comparable in structure and functionality to traditional coagulants.

Literature shows that the coagulation problem in cow and camel milk mixtures is structural in nature. It is associated with micellar heterogeneity and asynchronous aggregation. Plant extracts can act as aggregation pathway modifiers. However, their effect depends on the extract's composition and the process conditions.

Table 5 – Comparative analysis of plant modifier classes in the context of cow/camel milk mixtures

Criterion	Plant proteases	Polyphenols	Pectins	Ionic factors ($CaCl_2$)	Applicability in cow/camel milk mixture
Coagulation mechanism	Enzymatic hydrolysis of κ-casein	Bridging / complex formation	Depletion / electrostatic complex	Inter-micellar bond reinforcement	All mechanisms can work simultaneously – combined effects poorly studied in mixed systems
Selectivity	Lower than chymosin; broad proteolysis	Non-enzymatic; no κ-casein specificity	Non-enzymatic	Non-enzymatic	Low MCA/PA of plant proteases is a risk – excessive proteolysis worsens protein retention
Effect on curd yield	Comparable to chymosin when optimised (kiwi, pumpkin)	May improve via network densification at moderate levels	Reduces syneresis (higher yield via water retention)	Can increase yield through faster network formation	Combination of pectin + $CaCl_2$ may be most relevant for camel milk micelle integration
Main limitation	Narrow temperature optimum; variable MCA/PA	High concentration causes off-flavour and structural defects	Effect highly dependent on esterification degree and Ca^{2+} level	Excess causes syneresis and rigid gel	No standardised protocols for mixed milk systems – direct comparison between studies impossible
Nutritional impact	Risk of protein fragmentation in whey	Reduced protein digestibility via complex formation	Minor – dietary fibre addition	Negligible	Nutritional tradeoffs of polyphenol-protein interactions rarely addressed in applied studies

Key gaps remain:

– Extracts are rarely standardized by composition;
– Gel microstructure is rarely analyzed;
– Little data exists on protein loss in whey by fraction;
– Studies on the digestibility of protein–polyphenol complexes are limited;
– Few models describe heterogeneous aggregation in mixtures.

These gaps form the basis for further mechanistic research and rational process design.

It is also important to note that temperature and pH have a significant impact on the activity of milk-clotting enzymes from plant sources. Optimal activity ranges vary depending on the plant and the specific protease, requiring adaptation of process parameters for each specific case. Without standardized conditions, it is impossible to compare results or apply them in practice.

Thus, plant proteases can act as functional coagulants, but their use requires precise control of process parameters: temperature, pH, calcium concentration, and coagulation time. Furthermore, their impact on the micro- and macrostructure of the gel must be analyzed in terms of fractional protein retention, not just visual clot formation.

Conclusion

The review showed that plant extracts have the ability to modulate the milk coagulation process through enzymatic and colloidal mechanisms. Many plants contain proteases that can break down κ-casein and initiate micelle aggregation, making them potential alternatives to animal and microbial coagulants. Their effectiveness and impact on product properties depend on the specificity of the enzymes, process conditions (pH, temperature, calcium concentration), and the composition of the source milk.

Plant proteases can improve protein retention and modify the network structure, but are often accompanied by decreased selectivity, excessive hydrolysis, and altered gel quality. This emphasizes the need for a mechanistic approach to their use, including optimization of process parameters.

Further research should ensure:

– standardization of extracts by composition and activity,

– study of the effect of proteases on the micro- and macrostructure of the gel,

– modeling of the interaction of plant enzymes with milk proteins at the molecular level;

– assessment of the impact on the nutritional and organoleptic properties of finished products.

Only such an interdisciplinary approach will enable the use of plant extracts as complete and controllable coagulation modifiers in dairy systems, including complex mixtures such as cow's and camel's milk.

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СИЫР МЕН ТҮЙЕ СҮТІНІҢ ҚОСПАЛАРЫНДА АҚУЫЗДЫҢ КОАГУЛЯЦИЯСЫ МЕН САҚТАЛУЫНЫҢ ӨСІМДІК МОДИФИКАТОРЛАРЫ

Осы шолудың мақсаты-өсімдік сығындыларының сүт коагуляциясына әсер ету механизмдерін талдау және олардың сиыр мен түйе сүтінің қоспаларына қолданылуын бағалау. Шолу мақаласына кіретін сүт-өсімдік протеазаларының коагуляциялық белсенділігі, полифенол қосылыстарының казеин мицеллаларының агрегациясына әсері және процестің технологиялық параметрлерінің рөлі.

Талдау нәтижелері өсімдік сығындылары екі негізгі механизм арқылы әрекет ете алатынын көрсетеді. Бірінші механизм κ-казеиннің протеолитикалық гидролизімен және мицелла агрегациясының басталуымен байланысты. Екінші механизм полифенолдар мен пектиндік заттардың ақуыздармен өзара әрекеттесуіне байланысты, бұл гельдің бөлшектік өзара әрекеттесуі мен суды ұстау қабілетін өзгертеді. Сығындылардың тиімділігі олардың құрамына, концентрациясына, ортаның pH-на, температураға және кальций құрамына байланысты.

Дегенмен, өсімдік протеазалары көбінесе химозинмен салыстырғанда төмен селективтілікке ие. Бұл артық протеолизге және тромб құрылымының әлсіреуіне әкелуі мүмкін. Сиыр мен түйе сүтінің қоспаларында ақуыз профиліндегі және компоненттердің коллоидтық тұрақтылығындағы айырмашылық қосымша рөл атқарады.

Шолу өсімдік коагуляциясының модификаторларын қолдану перспективасын растайды, бірақ технологиялық жағдайларды дәл оңтайландыру және оларды қолдануға механикалық көзқарас қажеттілігін көрсетеді. Практикалық іске асыру үшін гельдің микроқұрылымын, ақуызды сақтауды және протеолитикалық белсенділіктің тепе-теңдігін бағалауға бағытталған зерттеулер қажет.

Түйін сөздер: *казеин, κ-казеин, қоспалар, сығындылар, гельдеу, синерезис, сүзбе, тұрақтылық.*

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РАСТИТЕЛЬНЫЕ МОДИФИКАТОРЫ КОАГУЛЯЦИИ И УДЕРЖАНИЯ БЕЛКА В СМЕСЯХ КОРОВЬЕГО И ВЕРБЛЮЖЬЕГО МОЛОКА

Цель настоящего обзора – проанализировать механизмы действия растительных экстрактов на коагуляцию молока и оценить их применимость для смесей коровьего и верблюжьего молока. В обзор включены публикации, посвящённые молоко-коагулирующей активности растительных протеаз, влиянию полифенольных соединений на агрегацию казеиновых мицелл и роли технологических параметров процесса.

Результаты анализа показывают, что растительные экстракты могут действовать через два основных механизма. Первый механизм связан с протеолитическим гидролизом κ-казеина и инициацией агрегации мицелл. Второй механизм связан с взаимодействием полифенолов и пектиновых веществ с белками, что изменяет межчастичные взаимодействия и водоудерживающую способность геля. Эффективность экстрактов зависит от их состава, концентрации, pH среды, температуры и содержания кальция.

Однако растительные протеазы часто обладают более низкой селективностью по сравнению с химозином. Это может приводить к избыточному протеолизу и ослаблению структуры сгустка. В смесях коровьего и верблюжьего молока дополнительную роль играет различие в белковом профиле и коллоидной стабильности компонентов.

Обзор подтверждает перспективность применения растительных модификаторов коагуляции, но подчёркивает необходимость точной оптимизации технологических условий и механистического подхода к их использованию. Для практической реализации требуются исследования, направленные на оценку микроструктуры геля, удержание белка и баланс протеолитической активности.

Ключевые слова: *казеин, κ-казеин, смеси, экстракты, гелеобразование, синерезис, творог, стабильность.*

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THE EFFECT OF ROSE HIP LEAF EXTRACT ON THE QUALITATIVE AND MICROBIOLOGICAL INDICATORS OF WHOLE GRAIN BREAD

Annotation: *An analysis was conducted of the organoleptic, physicochemical, and microbiological parameters of the finished product to determine the effect of rosehip leaf extract on the quality parameters of whole-grain bread and its shelf life.*

Rosehip leaf extract was used as a plant raw material. The effective amount of rosehip leaf extract has been established. Rosehip leaf extract contains biologically active substances belonging to different