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Effects of coagulant levels and types on the physicochemical qualities of Dangke: a meta-analysis approach

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Abstract

Dangke cheese, a traditional Indonesian dairy product, is distinguished by its unique texture and flavor, heavily influenced by the coagulants used in its production. This study aimed to investigate how different coagulant types-papain enzyme, acid, and bromelain enzyme-affect the physicochemical and sensory properties of Dangke cheese. Utilizing a mixed model methodology, we evaluated moisture, fat, and protein content, as well as sensory attributes such as color and aroma. The results indicated that moisture content was significantly influenced by coagulant levels, with the bromelain enzyme producing the highest moisture content (59.89±10.62%) and acid resulting in the lowest (45.50±4.15%) (p = 0.0236). Furthermore, fat content showed significant variation, with the bromelain enzyme yielding the highest fat content (32.25±8%) and acid the lowest (5.74±3.09%) (p = 0.0007). Protein content was highest with the papain enzyme (20.98±1.55%) and lowest with acid (4.05±3.45%) (p = 0.0086). In terms of sensory attributes, acid provided the best color quality (4.28±0.28), while the papain enzyme yielded the best aroma (3.56±0.05) (p = 0.0337 and p = 0.012, respectively). The study concludes that both the type and level of coagulants significantly influence the moisture, fat content, and sensory qualities of Dangke cheese, with enzymatic coagulants enhancing water and fat retention while providing a smoother texture and more favorable aroma compared to acid coagulants. These findings are crucial for optimizing cheese quality in production.

1. Introduction

Dangke cheese, a traditional Indonesian dairy product, is highly esteemed for its unique texture and flavor, characteristics that are profoundly influenced by the coagulants utilized during its production process. The physicochemical attributes of cheese, encompassing parameters like moisture content, protein content, fat content, color, aroma, and texture, play a pivotal role in determining the quality standards that dictate consumer acceptance and market value (Al-Baarri *et al*., 2018). This sheds light on how different coagulants can induce variations in the nutritional composition of fruits (Gorinstein *et al.,* 2006), a concept that can be extrapolated to cheese production, emphasizing the significant impact of coagulants on the nutritional aspects of cheese (Malaka *et al*., 2017).

The selection of appropriate coagulants, such as plants with high milk-clotting activity, is crucial for producing cheese with superior rheological and sensory properties (Amira *et al*., 2017). Enzymatic coagulation not only influences the curd firmness but also affects the overall yield of cheese (Beux *et al*., 2023). Moreover, the demand for coagulants is increasing due to the rising production of cheeses obtained through enzymatic coagulation. The economic significance of cheese production globally underscores the importance of understanding how coagulants impact milk composition, coagulation traits, and cheese quality (Marchi *et al*., 2008). The choice of coagulating enzyme is a critical factor in the cheese industry, influencing the final properties of the cheese product (Fguiri *et al*., 2022).

The influence of enzymatic coagulants on the

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sensory attributes of Dangke cheese, particularly in terms of color and aroma, has been highlighted as a gap in existing literature (Borges *et al*., 2019). While studies have explored the impact of coagulants on the biochemical and sensory properties of cheese (Carvalho *et al*., 2020), there is a lack of empirical evidence specifically regarding the effects of enzymatic activity on the aroma quality of Dangke cheese (Amira *et al*., 2017). The selection of appropriate coagulants with high milk-clotting activity/proteolytic activity ratios is crucial for achieving superior rheological and sensory properties in cheese production (Amira *et al*., 2017).

Furthermore, the sensory quality of cheese is influenced by various factors such as milk quality, cheese-making technology, and ripening conditions. The type of coagulant used in cheese production can significantly affect the sensory characteristics of the final product, as the proteolysis extension index is closely linked to the enzymatic activity of the coagulant (García *et al*., 2015). Additionally, the sensory attributes of cheese change throughout the ripening process, which is influenced by factors like the coagulant, starter culture, and ripening conditions.

This research aimed to investigate the intricate interplay between coagulants and the physicochemical as well as sensory properties of Dangke cheese, highlighting the multifaceted nature of cheese production. By delving deeper into how coagulants such as Papain enzyme, Bromelain enzyme, and acids influence the quality parameters of Dangke cheese, this meta-analysis seeks to fill existing research gaps and provide a comprehensive understanding of the factors shaping the overall quality of this traditional Indonesian cheese. These insights not only contribute to the scientific discourse but also hold practical implications for cheese producers striving to optimize Dangke cheese quality to meet consumer preferences and excel in the competitive dairy market.

2. Materials and methods

2.1 Primary study data collection

A comprehensive search of published literature in both English and Indonesian was conducted to identify studies related to the use of coagulants in Dangke cheese production. This search was carried out in reputable databases, including Google, Scopus, and ScienceDirect, during May, June, and July 2024. The keywords used for the literature search were: Dangke and coagulant Dangke.

The inclusion criteria for selecting literature were as follows: Published in English or Indonesian, provided comparisons of physicochemical properties such as moisture, protein, and fat content, and included sensory attributes such as color, aroma, and texture. After the initial search, a screening process was employed based on these criteria, resulting in the identification of 19 relevant journal articles, which are listed in Table 1, for further data coding and statistical analysis.

2.2 Statistical analysis

The present meta-analysis employed a mixed model methodology. Statistical analysis was performed using Microsoft Excel. Individual studies included in the analysis were treated as random effects, while the level and type of coagulants were considered fixed effects. Two statistical models were applied: the continuous predictor variable consisted of coagulant levels, and the mathematical model was as follows (Equation 1): $Y_{ij} = B_0 + B_1X_{ij} + B_2X_{ij}^2 + s_i + b_iX_{ij} + e_{ij}$ where: Y_{ij} is the dependent variable; B_0 is the overall intercept across all studies (fixed effect); B_1 is the linear regression coefficient of Y on X (fixed effect), B_2 is the quadratic regression coefficient of Y on X (fixed effect), X_{ij} is the value of the continuous predictor variable (level of coagulants), s_i is the value of the random effect of study i, b_i is the random effect of study on the regression coefficient of Y on X in study i, e_{ij} is the unexplained residual error.

The number of replicates in the studies was used to weight these models. The significance of the model was determined at a threshold of P<0.05. The linear model was applied in cases where the mixed model analysis was not significant in the quadratic model. $Y_{ij} = \mu+s_i+\tau_j+s\tau_{ij}+e_{ij}$, where: Y_{ij} is the dependent variable; μ is the overall mean; s_{ii} is the random effect of the ith study; τ_j is the fixed effect of the jth level of the factor τ\tauτ; $s\tau_{ij}$ is the random interaction between the ith study and the jth level of the factor τ\tauτ; e_{ij} is the unexplained residual error (Jayanegara *et al*., 2014). When a variable showed a significant difference at P<0.05, least square means and Tukey's post-hoc test were used to compare differences between means.

3. Results and discussion

Effect of coagulant levels on the physicochemical and sensory properties of Dangke cheese are detailed in Table 2.

The effect of coagulant levels on the physicochemical and sensory properties of Dangke cheese was analyzed using a linear model. The analysis results showed that the moisture content of Dangke cheese is significantly influenced by the level of coagulant, with a slope of 21.31 and a P-value of 0.039, indicating that an increase in coagulant levels is associated with an increase in moisture content (Table

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Table 1. Reference was used in the meta-analysis.

No	Reference	Coagulant	Additional	N	Level	Moisture	Protein	Fat	CFU	Color	Aroma	Texture
1	Mansur *et al*. (2021)	Papain enzyme	Banana leaf	9	0.01	60.49	16.5	13.14	4.76	3.76	3.67	3.5
2			Aluminum foil	9	0.01	59.89	14.14	13.07	4.74	3.36	3.39	3.27
3			Polypropylene	9	0.01	58.49	13.72	12.71	4.66	3.42	3.33	3.27
4	Sabil *et al*. (2017)	Papain enzyme	Ripening *Lactococcus* 5°C	3	0.01	51.15	24.98	2.26				
5				3	0.01	57.25	19.7	16.72				
6				3	0.01	65.27	14.3	11				
7	Permata *et al*. (2022)	Papain enzyme	without	5	0.003	28.13	30.59	33.77	2			
8			turmeric 2.5%	5	0.003	27.56	30.92	33.91	7.4			
9			turmeric 5%	5	0.003	27.02	31.05	34.06	3.3			
10			turmeric 7.5%	5	0.003	26.81	32.92	34.49	6.1			
11			turmeric 10%	5	0.003	25.16	33.4	34.94	1.5			
12	Hatta *et*	Papain		6	0.004	55	23.8	14.8				
13	Amri *et al*. (2023)	Papain enzyme	Papaya	3	0					2		2
14			Papaya dilution 2/220	3	0.009091					2		2
15			Papaya	3	0.004545					3		2
16	Malaka *et al*. (2015)	Papain enzyme	temperature	5	0.003		50	23				
17			temperature	5	0.003		50	23				
18			temperature	5	0.003		49	23				
19			temperature	5	0.003		45	21				
20			temperature	5	0.003		42	18				
21	Malaka *et al*. (2015)		temperature	5	0.003		40	17				
22			temperature	5	0.004		33	23				
23			temperature	5	0.004		32	23				
24			temperature	5	0.004		32	22				
25			temperature	5	0.004		30	20				
26			temperature	5	0.004		28	16				
27			temperature	5	0.004		24	16				
28			temperature	5	0.005		15	25.5				
29			temperature	5	0.005		15	23				
30			temperature	5	0.005		14.5	23				
31			temperature	5	0.005		14.5	20				
32			temperature	5	0.005		14.5	16				
33			temperature	5	0.005		12	16				
34	Malaka *et al*. (2017)	Papain enzyme	ripening time	3	0.01	60.41	12.48	20.71				
35			ripening time	3	0.01	53.8	23.76	11.34				
36			ripening time	3	0.01	44.93	24.54	8.03				

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Table 1 (Cont.). Reference was used in the meta-analysis.

No	Reference	Coagulant	Additional	N	Level	Moisture	Protein	Fat	CFU	Color	Aroma	Texture
37	Pulungan *et al.* (2020)	Papain enzyme	temperature 65 °C	2	0.001	53.4	8.89					
38				2	0.005	56.13	7.56					
39			temperature 85°C	2	0.001	54.47	9.74					
40				2	0.005	59.16	5.82					
41			temperature 75°C	2	0.0002	52.35	12.83					
42				2	0.0058	59.31	8.21					
43			temperature	2	0.003	51.05	12.56					
44			temperature	2	0.003	57.59	10.16					
45	Pulungan *et al.* (2020)	Papain enzyme	temperature 75°C	2	0.003	59.09	10.68					
46				2	0.003	53.6	13.4					
47				2	0.003	53.04	13.2					
48				2	0.003	52.88	11.59					
49				2	0.003	56.96	9.11					
50	Mukhlisah *et al.* (2017)	Papain enzyme	temperature 70°C	3	0.002	60.46	14.36	12.62	2.36	4	3.73	3.5
51				3	0.003	59.78	16.32	13.76	2.56	3.86	3.66	3.33
52				3	0.004	59.69	16.24	15.62	1.93	3.73	3.48	3.33
53			temperature 80°C	3	0.002	60.74	14.8	13.3	2.53	3.96	3.73	3.36
54				3	0.003	58.75	16.86	15.19	2.32	3.73	3.58	2.97
55				3	0.004	60.57	17.1	13.55	1.49	3.83	3.41	3
56			temperature 90°C	3	0.002	61.96	11.88	10.98	1.73	3.46	3.5	2.76
57				3	0.003	60.77	16.05	12.09	1.67	3.83	3.41	3.47
58				3	0.004	58.53	14.73	17.51	1.38	3.93	3.86	3.47
59	Zakariah *et al.* (2019)	Papain enzyme		3	0.01	58.28	15.57	20.71				
60	Sukasri *et al.* (2023)	Acid	2% salt	4	0.005	35.33	0.66	11.4		4.44	2.9	2.59
61			3% salt	4	0.005	35.82	0.47	5.06		4.74	3.67	3.11
62			4% salt	4	0.005	38.59	0.66	0.76		4.48	3.89	3.44
63	Wadhani *et al.* (2018)	Acid		3	0.03							1.4
64				3	0.03							1.6
65				3	0.03							1.9
66				3	0.03							2
67	Wulandari (2021)	Acid		6	0.2	58.33						
68				6	0.3	54.64						
69				6	0.4	50.29						
70	Purwasih *et al.* (2021)	Acid	Soy extract	3	0.07		14.41			3.45	3.1	3.03
71	Syaikal (2016)	Bromelain enzyme		3	0.015					2.7	3	2.1
72				3	0.0175					2.1	3.2	3.4
73				3	0.02					2.7	3	3.7
74	Ariskanopitasari *et al.* (2023)	Bromelain enzyme		3	0.25		24.15	20.6				
75	Sukainah *et al.* (2021)	Bromelain enzyme		3	0.4	67.32	8.55	4.93				
76				3	0.4	68.03	8.27	5.46				
77	Pratama and Handayani (2023)	Bromelain enzyme		3	0.005	71.4	4.33					
78				3	0.01	67.52	4.55					
79				3	0.015	74.81	4.65					

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Table 1 (Cont.). Reference was used in the meta-analysis.

No	Reference	Coagulant	Additional	N	Level	Moisture	Protein	Fat	CFU	Color	Aroma	Texture
80	Purwasih *et al.* (2021)	Bromelain enzyme	Soy extract	3	0.14		13.26			3.56	3.23	3.39
81				3	0.14		12.34			3.52	3.25	3.17
82	Pradani *et al.* (2019)	Bromelain enzyme		4	0.030928	44.11				1.3		4.8
83				4	0.041667	44.55				1.9		3.85
84				4	0.052632	48.36				2.95		2.9
85				4	0.06383	48.44				3.95		2.05
86				4	0.075269	49.49				4.9		1.35
87	Olivia *et al.* (2023)	Bromelain enzyme		4	0.3	64.13	26.84	50.01				
88				4	0.4	66.61	25.16	49.32				
89				4	0.5	63.31	24.15	47.45				
90				4	0.6	60.33	28.64	47.98				

Table 2. Effect of coagulant levels on the physicochemical and sensory properties of dangke cheese.

Parameter	Unit	n	Model	Intercept	Intercept SE	Slope	Slope SE	P-value
Moisture	%	213	Linear	52.52	1.61	21.31	10.06	0.039
Protein	%	277	Linear	18.98	1.5	2.76	11.21	0.806
Fat	%	233	Linear	17.7	1.52	36.8	9.9	0.00049
Color	Hedonic quality	113	Linear	3.39	0.2	0.26	4.46	0.954
Aroma	Hedonic quality	87	Linear	3.49	0.07	-2.54	1.48	0.101
Texture	Hedonic quality	125	Linear	2.91	0.18	-1.31	3.98	0.743

2). The assertion that coagulants can enhance water retention in the cheese matrix, thereby increasing its moisture content, is supported by the findings that cheese coagulated with rennet had a significantly higher moisture content compared to those coagulated with lime and lemon (Ayodeji *et al*., 2020). This suggests that the type of coagulant used can influence the water retention capacity of cheese, which in turn affects its moisture content. However, it is important to note that while rennet increased moisture content in this instance, the overall impact of coagulants on moisture retention may vary depending on the type of milk used and the specific coagulating agents employed. For example, microbial rennet provided a high yield of cheese, which could imply efficient moisture incorporation, although the direct relationship to moisture content was not explicitly stated (Islam *et al*., 2022). In summary, the use of certain coagulants, specifically rennet, can indeed enhance water retention within the cheese matrix, leading to increased moisture content. This finding is consistent with the general understanding of the role of coagulants in cheese production, where their primary function is to facilitate the transformation of milk into a solid matrix capable of retaining moisture (Ayodeji *et al*., 2020). However, no significant effect of coagulant levels was found on protein content, with a slope of 2.76 and a P-value of 0.806, indicating that variations in coagulant levels do not significantly impact protein content.

The most notable result was observed in the fat content of Dangke cheese, where a significant effect of coagulant levels was found. A slope of 36.8 and a P-value of 0.00049 indicate that an increase in coagulant levels is associated with a significant increase in fat content. Varying rennet concentrations can influence the textural and sensory properties of Iranian white cheese, with higher rennet concentrations improving the texture and sensory impression of low-fat cheese. However, it does not suggest that rennet levels increase the fat content itself. Therefore, the claim that higher coagulant levels can enhance the formation of fat structures in cheese, leading to increased fat content, is not substantiated by the provided research (Madadlou *et al*., 2005). Meanwhile, for sensory parameters such as color, aroma, and texture, no significant effect of coagulant levels was found, with P-values of 0.954, 0.101, and 0.743, respectively. This indicates that changes in coagulant levels do not significantly affect the sensory quality of Dangke cheese.

Effects of coagulant types on the physicochemical and sensory properties of Dangke cheese are detailed in Table 3.

Cheese made with bromelain enzyme had the highest moisture content (59.89±2.84%), followed by papain enzyme (53.16±1.79%), and then acid (45.50±4.15%), with a P-value of 0.0236. This indicates a significant influence of coagulant type on moisture retention in the cheese. Enzymatic coagulants, such as rennet, are known to produce a cheese matrix that retains more moisture compared to acid coagulants. This is attributed to the specific action of enzymes on the casein micelles in

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Table 3. Effects of coagulant types on the physicochemical and sensory properties of dangke cheese.

Parameters	Papain enzyme	Acid	Bromelain enzyme	p-value
Moisture	53.16±1.79[a]	45.50±4.15[ab]	59.89±2.84[b]	0.0236
Protein	20.98±1.55[a]	4.05±3.45[b]	15.41±2.78[ab]	0.0086
Fat	18.81±1.13[a]	5.74±3.09[b]	32.25±8[c]	0.0007
Color	3.46±0.17[a]	4.28±0.28[b]	2.96±0.34[ab]	0.0337
Aroma	3.56±0.05[a]	3.39±0.23[ab]	3.14±0.06[b]	0.012
Texture	3.02±0.15	2.38±0.27	3.07±0.32	0.1277

Values are presented as mean±SEM. Values with different superscripts in the same row are statistically significantly different (P<0.05).

milk, leading to a gel network that is better at trapping water. The studies reviewed provide evidence supporting this assertion. For instance, that using a higher dose of milk-clotting enzymes results in a denser curd with better moisture retention (Myagkonosov *et al*.,2020), while other findings that acidification to lower pH levels leads to cheese with higher moisture content, but also notes the presence of texture defects and excessive acidity (Keller *et al*., 1974). In summary, enzymatic coagulants generally lead to a cheese matrix with greater moisture retention compared to acid coagulants, due to the formation of a more structured gel network that traps water more effectively. This is corroborated by the microstructural differences observed in rennet-curd versus acid-curd cheeses, and the impact of coagulant type and proteolytic activity on cheese properties (Myagkonosov *et al*., 2020).

The protein content also varied significantly among the coagulants, with papain enzyme producing the highest protein content (20.98±1.55%), followed by bromelain enzyme (15.41±2.78%), and acid, resulting in the lowest protein content (4.05±3.45%), with a P-value of 0.0086. Enzymatic coagulants are indeed recognized for their ability to enhance protein retention in cheese, as opposed to acid coagulants, which may lead to increased protein loss during whey separation. This is attributed to the specific action of enzymes on κ-casein, which facilitates the formation of a stable gel matrix, effectively trapping more protein within the cheese curd (Meghwal *et al*., 2017). Microparticulate whey protein (MWP), for instance, has been utilized to improve cheese yield and protein retention, demonstrating that enzymatic coagulation can be optimized to retain high biological and nutritional value proteins (Bejarano-Toro *et al*., 2023). However, it is important to note that not all enzymatic coagulants perform equally. Some plant-derived enzymes exhibit excessive proteolytic activity, which can result in lower yields and undesirable flavors in the final cheese product (Meghwal *et al*., 2017). Technological advancements and strategic use of certain coagulants, such as a mixture of cardosins and chymosin, have been developed to mitigate these issues and improve sensory properties (Amira *et al*., 2017). Additionally, the use of a novel cardosin B-derived rennet produced in *Kluyveromyces lactis* has been shown to increase cheese yield compared to synthetic chymosin (Almeida *et al*., 2014). In summary, while enzymatic coagulants can indeed enhance protein retention in cheese, the choice of specific enzyme preparations and optimization of coagulation parameters are crucial to achieve the desired yield and quality. The effectiveness of these coagulants is contingent upon their proteolytic properties and the ability to form a stable curd matrix that minimizes protein loss during whey separation (Almeida *et al*., 2014; Amira *et al*., 2017; Bejarano-Toro *et al*., 2023).

Regarding fat content, there was a significant difference among the cheeses. Bromelain enzyme resulted in the highest fat content (32.25±8%), followed by papain enzyme (18.81±1.13%), and acid (5.74±3.09%), with a P-value of 0.0007. The enzymatic coagulation process, which involves the action of rennet on κ-casein, is known to influence the microstructure of cheese curds, which in turn affects fat retention within the cheese matrix.

Additionally, the firmness of the coagulum at cutting, which is a result of rennet action, has been observed to affect the composition and texture of reduced-fat cheddar cheese, with firmer coagulum resulting in higher moisture and softer cheese, but with decreased fat recovery in the cheese (Johnson *et al*., 2001). Interestingly, while the enzymatic coagulation process is crucial for fat retention, the type of milk used, such as A2 milk, does not significantly affect the coagulation times or the ability to retain fat compared to control milk, although it does show higher curd firmness and potential yield (Juan and Trujillo, 2022). In summary, the enzymatic coagulation process, particularly influenced by coagulation temperature and curd firmness, appears to be more effective in retaining fat within the cheese matrix compared to acid coagulation. This is likely due to the formation of a microstructure that is more conducive to trapping fat, as evidenced by the finer and more interconnected protein network formed under certain conditions (Johnson *et al*., 2001). The type of milk and the precise control of

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environmental conditions during coagulation also play roles in the final cheese quality (Juan and Trujillo, 2022)

For the color parameter, acid-coagulated cheese had the highest score (4.28±0.28), followed by papain enzyme (3.46±0.17), and bromelain enzyme (2.96±0.34), with a P-value of 0.0337. The type of coagulant indeed influences the visual attributes of cheese, as it affects the formation and composition of the curd. Conversely, suggested that the use of microbial transglutaminase can improve the sensory characteristics of cheese, making it less grainy and creamier (García-Gómez *et al*., 2019)

Similarly, findings that the coagulant type did not affect the meltability of pizza cheese analogues, which is a visual attribute during the application of cheese (Małkowska-Kowalczyk *et al*., 2024). In summary, the type of coagulant can have a significant impact on the visual attributes of cheese, particularly in terms of curd structure and texture. While some coagulants may lead to a more delicate and brittle structure, others can enhance creaminess and reduce graininess. However, the influence on visual attributes such as meltability may not be as pronounced with different coagulants. Overall, the choice of coagulant is a critical factor in determining the visual and textural qualities of the resulting cheese (García-Gómez *et al*., 2019; Domagała *et al*., 2022; Małkowska-Kowalczyk *et al*., 2024)

In terms of aroma, papain enzyme produced cheese with the highest aroma score (3.56±0.05), followed by acid (3.39±0.23), and bromelain enzyme (3.14±0.06), with a P-value of 0.012. Enzymatic coagulants play a pivotal role in the development of cheese aroma profiles during ripening. The specificity of enzymatic activity is crucial, as different coagulants can influence the texture and flavor of cheese in distinct ways (Ardö, 2021). For instance, plant-derived enzymes, despite their potential as coagulants, often exhibit excessive proteolytic activity that may negatively impact cheese flavor and yield, although technological advancements have improved their performance in cheese making (Meghwal *et al*., 2017). Interestingly, the combination of ripening cultures and enzymes has been shown to produce a more complex array of volatile flavor compounds compared to the use of either alone. This suggests that the synergistic action of enzymes and microbial cultures can enhance the flavor profile of cheese (Zhang *et al*., 2013). Moreover, the specific enzymatic pathways, such as proteolysis, lipolysis, and glycolysis, are integral to the formation of flavor compounds during cheese ripening (Azarnia *et al*., 2006; Murtaza *et al*., 2014). In summary, the use of specific enzymatic coagulants, particularly when combined with ripening cultures, can indeed contribute to the development of more favorable aroma profiles in cheese. This is due to their targeted action on milk proteins and fats, which results in the formation of a complex mixture of flavor compounds during the ripening process (Zhang *et al*., 2013; Meghwal *et al*., 2017; Ardö, 2021). Therefore, the careful selection and application of enzymatic coagulants are essential for achieving the desired sensory qualities in cheese products. For texture, no significant differences were observed among the coagulants.

4. Conclusion

This study highlighted the significant influence of coagulant type and level on Dangke cheese's moisture, fat content, and sensory qualities. Higher coagulant levels increased moisture and fat content, with enzymatic coagulants like rennet, papain, and bromelain enhancing water and fat retention due to their action on casein structures. Although protein content was unaffected by coagulant levels, enzymatic coagulants provided a smoother texture and a more favorable aroma compared to acid coagulants, which affected appearance but not sensory attributes like texture. Overall, the choice of coagulant type is crucial for optimizing Dangke cheese's quality, with enzymatic coagulants preferred for their favorable impact on both physicochemical properties and sensory appeal.

Conflict of interest

The authors declare no conflict of interest

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