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РОЗРОБКА КОМПЛЕКСНОГО ПОКАЗНИКА ЯКОСТІ МОРОЗИВА З УРАХУВАННЯМ ПАРАМЕТРІВ ОБЛАДНАННЯ ДЛЯ ПЕРЕРОБКИ

Якість промислово виробленого морозива визначається поєднанням споживчих характеристик та технологічно вимірюваних показників. У цьому дослідженні запропоновано методологію визначення комплексного показника якості (КПЯ), яка об'єднує сенсорні властивості (зокрема смак) з ключовими технологічними параметрами, такими як вміст жиру, збитість і час танення. Досліджено три комерційні зразки морозива на основі стандартних українських методик й нормалізації результатів. Розраховані значення КПЯ показують, що досягнення високої якості продукції потребує одночасної оптимізації як рецептури, так і параметрів роботи технологічного обладнання. Результати дозволяють сформулювати конкретні рекомендації щодо вдосконалення виробничих ліній для забезпечення збалансованої якості – з урахуванням споживчих очікувань щодо смаку, структури й консистенції та технологічних властивостей, таких як збитість і час танення.

Ключові слова: *морозиво, комплексний показник якості, органолептична оцінка, збитість, танення, технологічна оптимізація, обладнання.*

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DEVELOPMENT OF A COMPREHENSIVE QUALITY INDICATOR FOR ICE CREAM WITH CONSIDERATION OF PROCESSING EQUIPMENT PARAMETERS

The quality of industrially produced ice cream is determined by a combination of consumer-oriented and technologically measurable characteristics. This study proposes a Comprehensive Quality Indicator (CQI) methodology that integrates sensory attributes (primarily taste) with key processing-dependent parameters such as overrun (degree of air incorporation) and melting time. Using standard Ukrainian methodologies and CQI-based normalization, three ice cream products were evaluated. The resulting CQI values demonstrate that achieving high product quality requires optimizing both formulation and equipment operation. Based on the findings, the study recommends specific technological improvements for manufacturing lines that aim to align consumer preferences especially taste, structure, consistency, with desirable structural properties such as overrun (degree of air incorporation) and melting time.

Keywords: *ice cream, comprehensive quality indicator, sensory evaluation, overrun, melting time, technological optimization, equipment*

Introduction. In the modern food industry, the production of ice cream presents a unique challenge: it must meet both the sensory expectations of consumers and the rigorous technological standards required for industrial manufacturing. Ice cream is not only a dessert – it is a complex aerated emulsion-foam system with delicate structural properties formed during production. Characteristics such as taste, total fat, structure, consistency, overrun (degree of air incorporation) and melting time are crucial for consumer acceptance and are highly sensitive to variations in processing conditions.

Despite the development of regulatory standards in Ukraine (e.g., DSTU 4733:2007 and DSTU 4735:2007), many producers continue to rely on outdated or inflexible processing equipment. These systems are often unable to achieve the precise control necessary over freezing kinetics, air distribution, or structural stabilization, which are vital for ensuring uniform product quality. As a result, products may exhibit inconsistencies in creaminess, hardness, or resistance to melting, leading to consumer dissatisfaction and economic losses for manufacturers.

The core of this problem lies in the technological gap between production requirements and equipment capability. In particular, insufficient control of parameters such as draw temperature, dasher speed, and aeration rate directly impacts the microstructure of ice cream – specifically the size and distribution of ice crystals and air cells. These structural elements determine key physical properties like melting time and overrun (degree of air incorporation), which in turn affect organoleptic perception such as texture and mouthfeel. If freezing is too slow or aeration is uneven, the resulting product may contain large crystals or unstable foam, reducing its sensory appeal and shortening its shelf life [1].

Furthermore, producers often lack a unified framework for evaluating how processing variables translate into final product quality. Traditional assessments focus on individual parameters (e.g., fat content, sugar concentration, or taste), but these isolated metrics fail to capture the holistic performance of the product. Without an integrated evaluation system, it becomes difficult to identify which production adjustments are most effective in improving quality.

To address this challenge, there is a growing need for an objective, quantifiable metric that can link technological performance with consumer-oriented outcomes. One promising solution is the development of a Comprehensive Quality Indicator (CQI), which consolidates multiple physical and sensory variables into a single evaluative score. Such an indicator can serve not only as a diagnostic tool for identifying shortcomings in current production but also as a benchmark for optimizing equipment design and process control.

The study proposes the construction of a CQI tailored specifically to the Ukrainian ice cream market. It focuses on the most commonly consumed types of ice cream – such as classic "Plombir" and cream-based cones – and evaluates them based on three main parameters: taste (as the dominant sensory trait), overrun (degree of air incorporation) (as a marker of aeration quality), and melting time (as an indicator of structural stability). By analyzing how each of these parameters contributes to overall product quality, and how they are influenced by processing conditions, we aim to establish a scientific basis for improving production lines [2].

Ultimately, the objective is not merely to assess current products but to guide the development of technological strategies that can reliably produce ice cream with optimal organoleptic, physicochemical, and functional characteristics. The CQI will serve as a bridge between consumer satisfaction and industrial efficiency, helping manufacturers align equipment capabilities with market demands.

Analysis of recent studies. Recent scientific research confirms that ice cream quality depends not only on ingredients, but largely on the technological parameters of the equipment used during production. Studies by Inoue et al. have demonstrated that the settings of continuous freezers – specifically draw temperature, dasher speed, and aeration rate – significantly affect the size and distribution of ice crystals and air cells. These microstructural elements, in turn, determine product texture, hardness, and melting time [3]. Gallagher's research supports this, showing that dasher geometry directly influences freezing efficiency and residence time, which are critical for structure & consistency [4].

Other researchers have evaluated the effect of aeration equipment on foam characteristics. Narchi et al. showed that rotor–stator systems are effective for producing high overrun (degree of air incorporation) but can yield large bubbles, whereas stirred columns are better for fine foam structures but require higher energy inputs [5]. This engineering trade-off highlights the need for balanced control of aeration to ensure desirable texture and overrun (degree of air incorporation) without compromising stability [6].

Further studies emphasize the direct connection between freezing kinetics and consumer-perceived creaminess. Researchers noted that ice cream samples with smaller crystals and air cells were rated higher in taste and texture evaluations. These structural attributes are most effectively controlled by modern freezing and mixing systems, which provide the fine control needed for high-quality output [3, 5].

In Ukraine, research has focused primarily on the physical and microbiological aspects of ice cream and their compliance with national standards such as DSTU 4733:2007 and DSTU 4735:2007 [10, 11]. However, existing studies often treat quality indicators in isolation, without a comprehensive framework to combine technical and sensory parameters. For example, Narizhniy et al. examined sensory and physicochemical properties of low-calorie ice cream but did not attempt to unify these into a single metric that could guide equipment optimization [7, 8].

The absence of a unified evaluative system presents a gap in the literature. While producers measure fat content, overrun (degree of air incorporation), and taste individually, these indicators do not offer a comprehensive picture of how equipment parameters impact final product quality. This makes it difficult to identify process improvements or benchmark production efficiency. Asmaa Harfousha et al., note that many current industrial lines lack real-time integration of product quality data, leading to variability across production batches [13].

To address this issue, recent studies in related fields have proposed using Comprehensive Quality Indicators (CQI) to assess product performance holistically. For instance, Yaheliuk and Fomich successfully applied a CQI model to optimize fuel roll production by balancing structural and energy characteristics [2, 12]. Their methodology – based on weighted normalization of multiple criteria – can be adapted to ice cream evaluation by incorporating overrun (degree of air incorporation), melting time, and taste as core indicators.

Although CQI-type approaches have been occasionally explored in food science, their application to ice cream remains underdeveloped. Fedchenko et al. were among the first in Ukraine to propose a complex evaluation system for ice cream, integrating sensory, physicochemical, and microbiological characteristics [1]. However, their model lacked a strong focus on processing parameters and did not link quality outputs to equipment design.

Taken together, these findings point to the need for a modern, processing-aware CQI model tailored to ice cream production. Such a model would not only allow for comparative evaluation of popular

Ukrainian ice cream types but also inform targeted upgrades of equipment and technology to improve consistency, consumer satisfaction, and production efficiency

The aim. The aim of this study is to develop a comprehensive Quality Indicator (CQI) for ice cream that explicitly includes processing equipment effects. We will focus on three critical metrics: (1) overrun (degree of air incorporation) (the percent increase in volume from air incorporation during freezing), (2) melting time (resistance to melt under standard conditions), and (3) sensory taste score. The CQI will be a weighted combination of these metrics, reflecting both production performance and consumer satisfaction. By quantifying quality in this integrated way, we can provide clear recommendations for optimizing ice-cream manufacturing lines (e.g. freezer design and settings) to produce better-tasting products with desired texture and melt properties.

Materials and Methods. This study included the evaluation of three commercially available ice cream products representative of the most consumed types in Ukraine: Plombir in chocolate glaze (TM "Limo"), sugar-free Classic Plombir (TM "Maxkholod"), and creamy cone “Eclair Brownie Monaco” (TM "Tri Vedmedi"). All samples were certified in accordance with Ukrainian national standards DSTU 4733:2007 and DSTU 4735:2007, which regulate both compositional and sensory requirements for ice cream products [10, 11].

Sensory evaluation was carried out in accordance with DSTU 4733:2007. Trained panelists assessed product appearance, color, internal structure, consistency, aroma, and flavor. Evaluation was conducted under standardized lighting and temperature conditions, using a 5-point hedonic scale. Sensory defects such as glaze cracking, color irregularities, graininess, or off-odors were recorded as deviations from normative benchmarks. Each sensory test was performed in triplicate, with mean scores used in further analysis.

Standardized methods were applied to ensure reproducibility of freezing parameters and their control using modern production systems [6]. Moisture and total solids content were measured gravimetrically via oven drying at 110–112 °C to constant weight, according to DSTU 8552:2015 [14] and AOAC procedures [4]. Fat content was determined using the Gerber butyrometric method in accordance with ISO 2446:2008 [3, 8]. Titratable acidity was measured by titration with 0.1 N NaOH using phenolphthalein as an indicator, and pH values were recorded using a calibrated potentiometric pH meter. Sugar content was quantified by the Bertrand copper reduction method. Overrun (degree of air incorporation) was measured as the percentage difference in weight between aerated and melted product, per DSTU 4733:2007. Melting time was determined by measuring the time required for 10 mL of meltwater to pass through a funnel at 20 ± 2 °C from a 50 g ice cream sample.

To synthesize a unified quality measure, a Comprehensive Quality Indicator (CQI) was introduced. This index reflects a weighted integration of selected sensory and technological parameters that influence consumer perception and industrial performance. The initial pool of parameters considered for inclusion comprised ten indicators: external appearance, color, structure and consistency, aroma, taste, fat content, total sugar, titratable acidity, overrun, and melting time. To determine the most relevant criteria for inclusion in the final CQI, an expert elicitation procedure was used.

A panel of six qualified experts with backgrounds in dairy technology, food engineering, and sensory analysis participated in the selection and weighting process. Each expert independently ranked the importance of the ten initial parameters. After aggregation and comparative analysis of expert input, five key indicators were selected for CQI modeling: taste, structure and consistency, total fat content, overrun (degree of air incorporation) percentage, and melting time. Final weights were assigned to each criterion based on normalized rankings, reflecting both technological relevance and consumer impact.

All analytical and sensory measurements were performed in triplicate. The resulting CQI scores were used to compare product performance across samples and assess alignment with national quality standards and consumer expectations.

Results. The study evaluated three widely available industrial ice cream products representing different compositional and technological formats: Plombir in chocolate glaze (TM “Limo”), Classic sugar-free Plombir (TM “Maxkholod”), and the Cream Cone “Eclair Brownie Monaco” (TM “Tri Vedmedi”).

A standardized methodology was applied to calculate the Comprehensive Quality Indicator (CQI) for ice cream samples, based on multi-criteria normalization and weighted aggregation of key quality parameters. The overall quality score was derived using the following model:

$$CQI = \sum_{i=1}^{n} W_i \times P_i \, , \quad (1)$$

where W_i – the weight coefficient reflecting the significance of parameter i for ice cream quality; P_i – the normalized value of parameter i scaled to a dimensionless range between 0 and 1.

Tabl. 1

General Information about Ice Cream Samples

Attribute	Plombir in Chocolate Glaze (TM "Limo")	Classic Sugar-Free Plombir (TM "Maxkholod")	Cream Ice Cream Cone “Eclair Brownie Monaco” (TM "Tri Vedmedi")
Product Type	Plombir Ice Cream in Chocolate Glaze	Classic Plombir Ice Cream, Sugar-Free	Cream Ice Cream Cone “Eclair Brownie Monaco”
Brand	Limo	Maxkholod	Tri Vedmedi
Net Weight, g	80	80	100
Manufacturer	PJSC “Lviv Cold Storage Plant”, 2 Povitryana St., Lviv	LLC “Maxkholod”, Dmytrivka, Bucha District, Kyiv Region	LLC “Tri Vedmedi”, 65 Kozatska St., Berdychiv, Zhytomyr Region
Regulatory Standard	DSTU 4733:2007 – Milk, Cream, and Plombir Ice Cream. General Specifications	DSTU 4733:2007 – Milk, Cream, and Plombir Ice Cream. General Specifications	DSTU 4735:2007 – Ice Cream with Combined Raw Material Composition. General Specifications
Nutritional Value per 100 g:			
– Proteins, g	3.3	4.1	4.6
– Total fats, g (saturated)	21.7 (7.2)	12.3 (7.2)	11.2 (4.3)
– Carbohydrates, g (sugars)	24.2 (18.2)	5.5 (4.5)	29.9 (17.0)
Energy Value, kcal/100 g	305	149.1	242

The assessment was carried out through a multiparametric analysis framework, aimed at quantifying product quality through five principal indicators: sensory (taste), structure and consistency, total fat content, overrun (degree of air incorporation) (air incorporation), and melting time. These indicators were selected to integrate both consumer-relevant attributes and manufacturing-critical physical parameters, thereby enabling simultaneous evaluation of technological performance and sensory satisfaction.

The weighting of parameters was performed using an expert-based approach. Experts independently evaluated the importance of each parameter on a scale from 1 to 10. The individual scores S_{ij} assigned by expert j for parameter i were aggregated to determine the average importance

$$S_i = \frac{1}{m} \sum S_{ij}, \tag{2}$$

where m is the number of experts.

The resulting average scores Si were then normalized to ensure that the total sum of weights equaled 1, following the equation:

$$W_i = \frac{S_i}{\sum S_i}. \tag{3}$$

This procedure yielded the relative weights used in the CQI model. Statistical methods were employed to assess the consistency of expert evaluations, including measures of standard deviation and coefficient of variation.

The normalized score P_i for each parameter was calculated to transform raw measurements into dimensionless units, ensuring comparability across different metrics. The normalization formula was selected based on the direction of correlation between the parameter and perceived quality. For indicators with direct correlation (e.g., taste, structure, fat content, overrun), the normalization was conducted as:

$$P_i = \frac{\text{MeasuredValue}}{\text{BenchmarkValue}}, \tag{4}$$

For attributes with inverse correlation, where lower values indicate better quality (such as melting time), the normalization was inverted:

$$P_i = \frac{\text{BenchmarkValue}}{\text{MeasuredValue}}. \tag{5}$$

This methodological framework was applied to evaluate three commercially available ice cream (table 1), enabling an objective and integrated quality assessment. All measurements were performed in triplicate to ensure data reliability, with calibrated instruments and controlled testing conditions to ensure reproducibility. The results are presented in Table 2.

Tabl. 2

Normalized Quality Parameters of Ice Cream Samples

No.	Parameter	Benchmark	Limo	Tri Vedmedi	Maxkholod	Wi	Correlation
1	Taste	5	4	4	5	0.20	Direct
2	Structure & consistency	5	3	4	4	0.14	Direct
3	Total fat, %	16	19.6	11.3	14.4	0.12	Direct
4	Overrun (degree of air incorporation), %	85	86	95	88	0.16	Direct
5	Melting time, min	60	77	52	60	0.16	Inverse

Using the normalized values and the expert-derived weights, the comprehensive quality indicator (CQI) was calculated for each of the analyzed ice cream samples. The results of this evaluation are presented in Table 3.

Tabl. 3

Comprehensive Quality Indicator (CQI) Results

Ice Cream Sample	CQI Value
Plombir in chocolate glaze (TM "Limo")	0.86
Eclair Brownie Cone (TM "Tri Vedmedi")	0.66
Classic Plombir without sugar (TM "Maxkholod")	0.74

Among the tested products, the highest integral quality score was achieved by the Plombir in chocolate glaze (TM “Limo”), which scored 0.86 on the CQI scale. This result can be attributed to the sample’s high fat content (exceeding the benchmark value by over 20%), favorable melting time (77 minutes compared to a standard of 60 minutes), and overall solid sensory acceptance, despite scoring slightly below maximum in terms of structure. These technological and sensory strengths yielded high normalized values across most quality dimensions, effectively compensating for a minor structural deficiency.

The Classic Plombir without sugar (TM “Maxkholod”) ranked second, with a CQI value of 0.74. While this product achieved the highest possible score for taste (5.0) and satisfactory structure, its lower fat content (14.4% vs. the benchmark of 16%) and average melting stability constrained its final rating. The reduced fat level may be linked to the sugar-free formulation, which often necessitates adjustments in the fat-to-solid balance to maintain palatability and texture. Although its overrun (degree of air incorporation) was above the benchmark (88% vs. 85%), the relatively moderate weight of this parameter (Wi = 0.16) limited its compensatory effect.

The lowest CQI value (0.66) was observed in the Eclair Brownie Cone (TM “Tri Vedmedi”), largely due to the combination of a modest sensory rating (taste and structure both scored 4 out of 5), lower fat content (11.3%), and below-standard melting time (52 minutes). Despite achieving the highest overrun (degree of air incorporation) value (95%), the weak performance in high-weighted criteria such as melting time and sensory characteristics reduced the total CQI. This sample's composition — which includes non-dairy fat substitutes according to DSTU 4735:2007 – may have contributed to its diminished melt stability and perceived richness.

These findings highlight the significant role of each selected parameter within the weighted CQI framework. Notably, while parameters such as overrun (degree of air incorporation) may show high absolute values, their relative contribution to total quality remains dependent on both their normalized score and expert-assigned weight. For instance, although “Tri Vedmedi” excelled in overrun (degree of air incorporation), this alone could not compensate for sensory and compositional shortcomings, as those dimensions hold higher weight in determining consumer-perceived quality.

Moreover, the results validate the relevance of using a multi-criteria, weighted assessment model for quality evaluation. This approach allows researchers and manufacturers to quantify not just individual deviations from ideal standards but also the cumulative effect of multiple quality attributes. It becomes especially relevant in industrial contexts where formulation, ingredient substitution, and equipment settings (e.g., freezer draw temperature, homogenization pressure, aerator speed) must be finely tuned to optimize product performance holistically.

In this context, the CQI methodology offers several practical advantages. First, it enables a standardized comparison across diverse ice cream types and production formats. Second, it facilitates evidence-based decisions regarding process modifications or raw material substitutions. Finally, it provides a framework for continuous improvement by indicating which specific parameters most strongly influence the final product quality, based on consumer-relevant benchmarks and expert consensus.

The radar chart (fig.1) presented provides a comparative visualization of the normalized quality parameters of three industrial ice cream samples: Plombir in chocolate glaze (TM "Limo"), Eclair Brownie Cone (TM "Tri Vedmedi"), and Classic Plombir without sugar (TM "Maxkholod"). The evaluation encompasses five key indicators – taste, structure and consistency, total fat content, overrun (degree of air incorporation) (degree of aeration), and melting time – all of which were normalized relative to established benchmark values to facilitate inter-sample comparability.

From the graphical representation, several critical observations emerge. The "Limo" sample exhibits the highest normalized score for total fat content, significantly exceeding the benchmark reference (normalized value > 1.0). This is indicative of its superior richness, a factor positively correlated with both sensory appeal and textural stability. However, the same sample demonstrates a relatively lower score in structure and consistency, suggesting slight deficiencies in structure and consistency or resistance to mechanical deformation during consumption. Nonetheless, its melting time and overrun (degree of air incorporation) values are within acceptable normalized ranges, collectively contributing to its leading comprehensive quality indicator (CQI) score.

In contrast, the "Tri Vedmedi" product achieves the highest value in overrun (degree of air incorporation), reflecting superior air incorporation during freezing. However, it performs less favorably in both taste and melting time – attributes critical to consumer perception and overall structural performance. The relatively low fat content further diminishes its normalized quality score in that dimension, which collectively leads to its lowest CQI value among the three samples.

The "Maxkholod" sample demonstrates a well-balanced profile. It achieves the highest normalized score in taste (1.0), indicating optimal flavor quality per expert assessment. Structure & consistency is also favorable, while fat content and overrun (degree of air incorporation) are moderately aligned with benchmark targets. Notably, its melting time matches the reference value, contributing positively to its overall CQI. While it does not outperform in any singular dimension, its consistent performance across multiple indicators results in an intermediate quality rank.

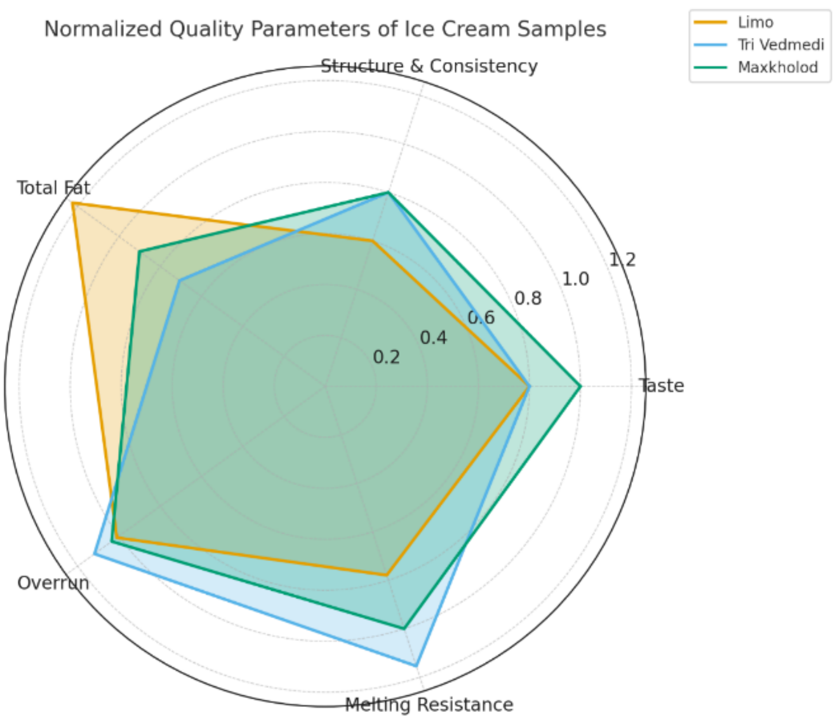

Fig 1. **Radar chart showing normalized scores for ice cream quality parameters**

Based on the results of the CQI analysis and the radar profile of normalized parameters, several recommendations can be made regarding technological improvements in ice cream production equipment:

- Aeration control systems should be fine-tuned to ensure consistent overrun (degree of air incorporation) without compromising melting time. Equipment should allow for adjustable overrun (degree of air incorporation) targets depending on product type and desired sensory attributes.
- Freezing and hardening equipment must provide precise control over draw temperature and residence time to enhance melting time and minimize structural defects such as ice crystal formation or glaze cracking.
- Homogenization units should be optimized to enhance the uniformity of structure and consistency. Upgraded pressure regulation systems and two-stage homogenizers can help improve fat dispersion and product smoothness.

Fat integration modules (especially in products with reduced sugar or dairy content) should allow for precise blending and emulsification. This is particularly relevant for sugar-free and combined-ingredient formulations like TM "Maxkholod" and TM "Tri Vedmedi".

Thus, the CQI approach, when applied systematically, serves not only as a diagnostic tool for quality differentiation but also as a strategic instrument for optimizing production technology in the ice cream industry. Further research could explore its applicability in broader product categories and validate its predictive power in consumer preference modeling. This study confirms that a structured CQI methodology can effectively capture and quantify quality differences among industrial ice cream products, and can serve as a tool for optimizing equipment settings and formulation design.

Conclusions. This study confirms that a Comprehensive Quality Indicator (CQI) provides a robust framework for evaluating and comparing industrial ice cream products. The methodology effectively integrates both consumer-relevant parameters (taste) and technological attributes (overrun (degree of air incorporation) and melting time), reflecting real-world production and consumption conditions.

The highest CQI score was achieved by the sample with a well-balanced combination of high fat content and melting time, indicating the critical role of processing equipment in shaping product quality. Specifically, the results underline that improving dasher configuration, air injection systems, and draw temperature control can significantly enhance ice cream texture and prolong melting time, thus increasing consumer satisfaction.

We recommend the following steps for manufacturers: optimize overrun (degree of air incorporation) levels through precise control of aeration equipment to balance texture and energy use; improve melting time by adjusting freezing temperature and dasher shear rate to refine microstructure; align sensory expectations with process outputs via routine CQI assessments during product development.

These recommendations support the development of high-quality ice cream that satisfies both market demand and technical efficiency, thereby contributing to improved production practices in the food engineering sector.

References

1. Fedchenko, T.G., Skorchenko, T.A. and Pukhlyak, A.G., 2005. Determination of the general complex indicator of ice cream quality. *Dairy Industry,* (6), pp.45–47.

2. Yaheliuk, S. and Fomich, M., 2025. Optimizing fuel rolls from crop residues using comprehensive quality indicator (CQI). In: Proceedings of the 24th International Scientific Conference “Engineering for Rural Development”, Vol. 25, Jelgava, Latvia, 22–24 May 2025. pp.491–496.

3. Inoue, K., Ochi, H., Taketsuka, M., Saito, H., Sakurai, K., Ichihashi, N., Iwatsuki, K. and Kokubo, S., 2008. Modeling of the effect of freezer conditions on the principal constituent parameters of ice cream by using response surface methodology. *Journal of Dairy Science,* 91(5), pp.1722–1732. https://doi.org/10.3168/jds.2007-0796

4. Gallagher, L.R., 2024. Effect of Dasher Design on Residence Time and Microstructure of Frozen Desserts Produced with a Continuous Scraped Surface Freezer. PhD thesis. University of Wisconsin. Available at: https://asset.library.wisc.edu/1711.dl/6RYM63LYGTDTY84/R/file-23650.pdf [Accessed 11 Nov. 2025].

5. Narchi, I., Vial, C., Labbafi, M. and Djelveh, G., 2011. Comparative study of the design of continuous aeration equipment for the production of food foams. Journal of Food Engineering, 102(2), pp.105–114. https://doi.org/10.1016/j.jfoodeng.2010.07.030

6. Sukhenko, Y.H., Polishchuk, H.Ye. and Sarana, V.V., 2019. Scientific and Technical Support for Ice Cream Production: monograph. Edited by H.Ye. Polishchuk. Kyiv: NUBiP of Ukraine. 299 c.

7. Narizhniy, S., Lomova, N., Rudakova, T. and Minorova, A., 2022. Quality Evaluation Research of

Low-Calorie Milk Ice Cream. Technologiya vyrobnyctva i pererobky produktiv tvarynnyctva, 2(175), pp.64-69.

8. Cartwright, G., McManus, B., Leffler, T. and Moser, C., 2005. Rapid Determination of Moisture/Solids and Fat in Dairy Products by Microwave and Nuclear Magnetic Resonance Analysis. Journal of AOAC International, 88(1), pp.42–51.

9. International Organization for Standardization, 2008. ISO 2446:2008 (IDF 226:2008). Milk – Determination of fat content (Gerber method). Geneva: ISO.

10. State Consumer Standard of Ukraine, 2008. *DSTU 4733:2007. Milk, Cream and Plombir Ice Cream. General Technical Specifications*. Kyiv: Derzhspozhyvstandart of Ukraine.

11. State Consumer Standard of Ukraine, 2008. *DSTU 4735:2007. Ice Cream with Combined Raw Material Composition. General Technical Specifications*. Kyiv: Derzhspozhyvstandart of Ukraine.

12. Kozhemiaka, O.V. and Peshuk, L.V., 2025. Comprehensive quality assessment of meat products with microalgae Chlorella. *Food Resources*, 13(24), pp.138–149. https://doi.org/10.31073/foodresources2025-24-15

13. Harfousha, A., Fan, Z., Goddik, L. and Haapala, K.R., 2024. A Review of Ice Cream Manufacturing Process and System Improvement Strategies. Manufacturing Letters, 41, pp.170–181. https://doi.org/10.1016/j.mfglet.2024.09.021

14. State Consumer Standard of Ukraine, 2015. DSTU 8552:2015. Ice Cream. Methods for Determination of Moisture and Total Solids. Kyiv: Derzhspozhyvstandart of Ukraine.