

Effect of Final Tempering Temperature Variations on the Physical Characteristics (Hardness and Gloss) of Dark Couverture and Milk Couverture

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Article History

Received : 15 January 2026
Revised : 25 February 2026
Accepted : 02 April 2026
Published : 16 June 2026

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DOI:

<https://doi.org/10.56127/ijml.v5i2.2787>

Abstract: This study aimed to analyze the effect of final tempering temperature variations on the physical characteristics of dark couverture and milk couverture, particularly hardness and gloss. The study used a qualitative experimental approach based on visual and tactile observations, field notes, and photographic documentation. Dark and milk couverture samples were treated at final tempering temperatures of 28°C, 30°C, and 32°C, then molded and evaluated using observation rubrics. The data were analyzed through data preparation, data reduction, coding, theme grouping, data display, preliminary conclusion drawing, and verification. The findings indicate that final tempering temperature affected hardness and gloss in both types of couverture. Dark couverture showed its highest visual gloss at 28°C, a balanced hardness-gloss response at 30°C, and the strongest mechanical resistance at 32°C. Milk couverture showed the highest hardness at 28°C, a balanced response at 30°C, and the highest gloss but lower hardness at 32°C. These findings confirm that dark and milk couverture respond differently to final tempering temperature because of differences in cocoa butter, cocoa solids, sugar, and milk components. This study provides an observation-based framework for chocolate tempering evaluation in culinary laboratories and small-scale confectionery practices.

Keywords: couverture, final temperature, gloss, hardness, tempering.

INTRODUCTION

Couverture chocolate is widely used in pastry, confectionery, praline production, coating, and food decoration because it provides specific melting behavior, texture, and surface appearance. Product quality is not only determined by raw material composition but also by processing control, particularly tempering. Tempering is a controlled sequence of melting, cooling, and reheating that aims to regulate cocoa butter crystallization and stabilize the fat network in chocolate. A stable fat structure is associated with firmness, clean mold release, surface gloss, and reduced risk of blooming ((Afoakwa, 2016); (Hartel et al., 2018)).

In practical chocolate processing, inappropriate final tempering temperature can produce soft chocolate, dull surfaces, weak shape retention, poor mold release, and white spots on the surface. These defects are related to non-uniform fat crystallization and insufficient structural stability. (Castro-Alayo et al., 2023) reported that tempering and fat composition affect crystallization kinetics, polymorphism, melting behavior, and the physical properties of chocolate. (Chen et al., 2021) also emphasized that minor lipid components can influence the crystallization pathway of cocoa butter and chocolate. Chocolate quality is also influenced by the type of couverture. Dark couverture generally contains higher cocoa mass and cocoa butter, whereas milk couverture contains milk solids

and milk fat that can influence viscosity, fat behavior, texture, and surface appearance. (Zarić et al., 2024) found that different chocolate types show different rheological, thermal, and textural properties. Therefore, the final tempering temperature suitable for dark couverture cannot be assumed to produce the same physical response in milk couverture.

Previous studies on chocolate tempering have mainly employed quantitative instruments such as differential scanning calorimetry, nuclear magnetic resonance, thermal analysis, or hyperspectral imaging ((Declerck et al., 2021); (Eriklioglu et al., 2025)). Although advanced analytical techniques can provide detailed information about cocoa butter crystallization and Form V polymorph formation, their use may be limited in culinary education laboratories and small-scale confectionery production due to equipment availability and technical requirements. For this reason, an observation-based qualitative experimental approach is relevant as an initial evaluation method. This approach allows the assessment of visible and tactile quality changes in tempered chocolate, including hardness, gloss, surface smoothness, deformation, and early signs of fat bloom, which are closely related to crystallization behavior and tempering quality ((Sato, 2018); (Wahyuni et al., 2021); (Stobbs et al., 2024)).

This study examined the impact of variations in the final tempering temperature on the physical qualities of dark and milk couverture chocolate, particularly focusing on hardness and gloss. The specified features are influenced by tempering conditions, which affect the chocolate's texture, surface appearance, and stability of the finished product (Nguyen et al., 2025). This study's innovation lies in its qualitative experimental design, which is underpinned by observation rubrics, photographic documentation, coding, and comparative interpretation. The research is anticipated to serve as a valuable resource for culinary education, laboratory methodology, and small-scale chocolate manufacturing, offering a practical framework for assessing and analyzing the quality of tempering.

Table 1. State of the art, research gap, novelty, and contribution of the study

Aspect	Description	Main references
State of the art	Tempering affects fat crystallization, melting behavior, texture, surface appearance, and blooming tendency in chocolate.	(Castro-Alayo et al., 2023); (Stobbs et al., 2025)
Strength of previous studies	Previous studies mainly used laboratory instruments to explain chocolate changes quantitatively and thermally.	(Declerck et al., 2021); (Eriklioglu et al., 2025)
Research gap	Comparative analysis of dark and milk couverture at different final tempering temperatures remains limited, especially through observation-based qualitative experiments.	(Zarić et al., 2024); (Nguyen et al., 2025)
Novelty	This study develops observation rubrics, coding procedures, and interpretation matrices to evaluate hardness and gloss without claiming direct identification of specific crystal forms.	(Miles et al., 2014);(Braun & Clarke, 2021)
Contribution	The study provides a practical procedure, observation instrument, documentation guide, and discussion format for culinary laboratories and small-scale chocolate production.	(Afoakwa, 2016); (Hartel et al., 2018)

Source: Processed by the Authors (2026)

Table 1 clarifies the academic position of the study. Previous research has strongly explained chocolate tempering through instrumental and thermal measurements. This study complements those works by emphasizing qualitative observation, coded documentation, and comparative interpretation between dark and milk couverture. This position is important because culinary laboratories and small producers often require an accessible evaluation model before applying advanced instrumental analysis.

The research questions were: (1) How does final tempering temperature influence the hardness of dark couverture and milk couverture? (2) How does final tempering temperature influence the gloss of dark couverture and milk couverture? (3) Do dark couverture and milk couverture show different physical responses to final tempering temperature variations? The objective was to analyze changes in hardness and gloss caused by final tempering temperature and to compare the responses of dark and milk couverture.

Table 2. Working hypotheses of the study

Code	Working hypothesis
H1	Final tempering temperature variations affect chocolate hardness qualitatively.
H2	Final tempering temperature variations affect chocolate surface gloss qualitatively.
H3	Dark couverture and milk couverture show different physical responses to final tempering temperature variations.

Source: Processed by the Authors (2026)

Table 2 is written explicitly because the hypotheses should not only appear in the conceptual framework figure. H1 and H2 guide the analysis of the two main physical indicators, namely hardness and gloss. H3 guides the comparison between chocolate types. In a qualitative experimental design, these hypotheses function as working propositions that direct observation and interpretation rather than as statistical hypotheses

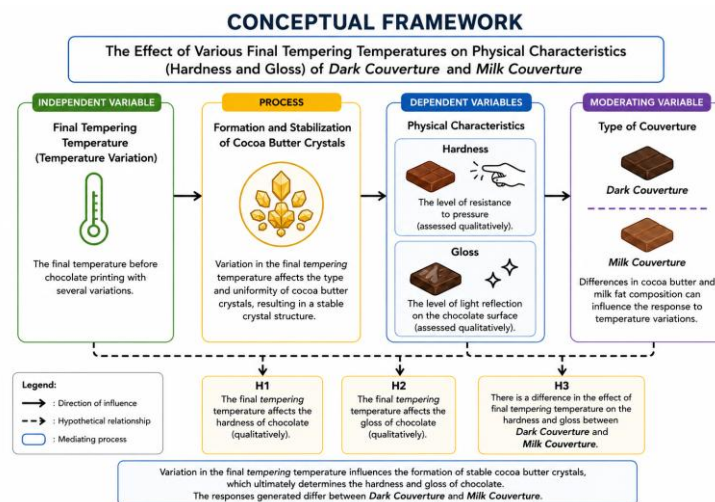


Figure 1. Conceptual framework of the effect of final tempering temperature on hardness and gloss of dark and milk couverture. Source: Processed by the Authors (2026)

Figure 1 positions final tempering temperature as the independent variable, fat structure formation as the mediating process, and hardness and gloss as dependent variables. Type of couverture is treated as a differentiating variable because dark and milk

couverture contain different proportions of cocoa butter, cocoa solids, sugar, and milk components. The framework also shows that the effect of temperature should be interpreted through both physical observation and comparison between sample groups

RESEARCH METHOD

This study used a qualitative experimental design. The design was selected because the study aimed to observe physical changes in chocolate caused by different final tempering temperatures. The main data consisted of visual observation, tactile observation, field notes, and photographic documentation of hardness, gloss, surface condition, deformation, and mold release.

The experiment was conducted in a food processing or pastry laboratory. The objects were dark couverture and milk couverture. The treatments were final tempering temperatures of 28°C, 30°C, and 32°C. These temperatures were used to compare the response of chocolate samples within a simple laboratory-scale tempering procedure.

The main materials were dark couverture and milk couverture from the same brand and batch to minimize material variation. Equipment included a digital scale, digital thermometer, stainless steel bowl, spatula, scraper, chocolate mold, working table, camera, and observation sheets. Equipment that came into direct contact with chocolate was kept clean and dry because moisture can disturb chocolate texture and surface quality.

Table 3. Operational definitions of research variables

Variable	Operational definition	Observation indicator	Recording technique
Final tempering temperature	The final temperature of the chocolate mass before molding after melting, cooling, and reheating.	28°C, 30°C, and 32°C.	Measured using a digital thermometer immediately before molding.
Hardness	The resistance of hardened chocolate to light pressure, deformation, and breakage.	Very soft, soft, moderately hard, hard, very hard.	Observed through light pressure and deformation response without a texture analyzer.
Gloss	The degree of light reflection and surface uniformity after molding and setting.	Very dull, dull, moderately glossy, glossy, very glossy.	Observed under similar lighting and photo angle.
Type of couverture	Chocolate type used to compare different responses to final tempering temperature.	Dark couverture and milk couverture.	Recorded using sample codes D and M.
Stable fat structure	A conceptual physical condition shown by better firmness, smoother surface, and higher gloss based on observation.	Smooth surface, uniform gloss, stable texture, no visible blooming.	Not interpreted as a specific crystal form because no crystallographic instrument was used.

Source: Processed by the Authors (2026)

Table 3 prevents the interpretation from exceeding the scope of the method. The term stable fat structure is used as a conceptual observation term, not as a direct identification of a specific crystal form. This is important because the study did not use DSC, NMR, X-ray diffraction, or other crystallographic tools.

Table 4. Qualitative experimental treatment design

Sample code	Type of couverture	Final temperature	Observed data	Documentation
D28	Dark couverture	28°C	Hardness, gloss, surface condition, mold release, and blooming indication.	Photographed after molding and observation.
D30	Dark couverture	30°C	Hardness, gloss, surface condition, mold release, and blooming indication.	Photographed after molding and observation.
D32	Dark couverture	32°C	Hardness, gloss, surface condition, mold release, and blooming indication.	Photographed after molding and observation.
M28	Milk couverture	28°C	Hardness, gloss, surface condition, mold release, and blooming indication.	Photographed after molding and observation.
M30	Milk couverture	30°C	Hardness, gloss, surface condition, mold release, and blooming indication.	Photographed after molding and observation.
M32	Milk couverture	32°C	Hardness, gloss, surface condition, mold release, and blooming indication.	Photographed after molding and observation.

Source: Processed by the Authors (2026)

Table 4 defines sample coding. The code D indicates dark couverture and M indicates milk couverture. The numbers 28, 30, and 32 indicate the final tempering temperature. This coding system supports traceability from experimental treatment to observation, table interpretation, and photographic documentation.

Table 5. Observation rubric for chocolate physical characteristics

Aspect	Category	Observation criteria
Hardness	Very soft	Chocolate changes shape easily, is difficult to release from the mold, and has no clear breakage.
Hardness	Soft	Chocolate is partly set but still easily deformed under light pressure.
Hardness	Moderately hard	Chocolate can be released from the mold and is stable, but the breakage is not fully firm.
Hardness	Hard	Chocolate is firm, does not deform easily, and shows clearer breakage.
Hardness	Very hard	Chocolate is stable, breaks firmly, and does not soften quickly at room observation temperature.
Gloss	Very dull	The surface is opaque, does not reflect light, and appears visually unstable.
Gloss	Dull	The surface is uneven, and light reflection is weak.
Gloss	Moderately glossy	The surface starts to reflect light, but the gloss is not evenly distributed.
Gloss	Glossy	Clear light reflection appears on a smooth surface.
Gloss	Very glossy	The surface is highly smooth, strongly reflective, and visually uniform.

Source: Processed by the Authors (2026)

Table 5 was used to standardize qualitative observation. Although the assessment remained qualitative, the rubric reduced interpretive bias by applying the same categories across all samples. Consistent criteria are important when comparing gloss and hardness without instrumental measurements.

The experimental procedure consisted of six stages. First, dark and milk couverture were weighed in equal quantities. Second, the chocolate was melted until homogeneous. Third, the temperature was lowered to encourage initial fat structuring. Fourth, the temperature was raised or adjusted to the final treatment temperature. Fifth, the chocolate was molded and allowed to set. Sixth, the physical characteristics were observed and documented through photographs and observation sheets.

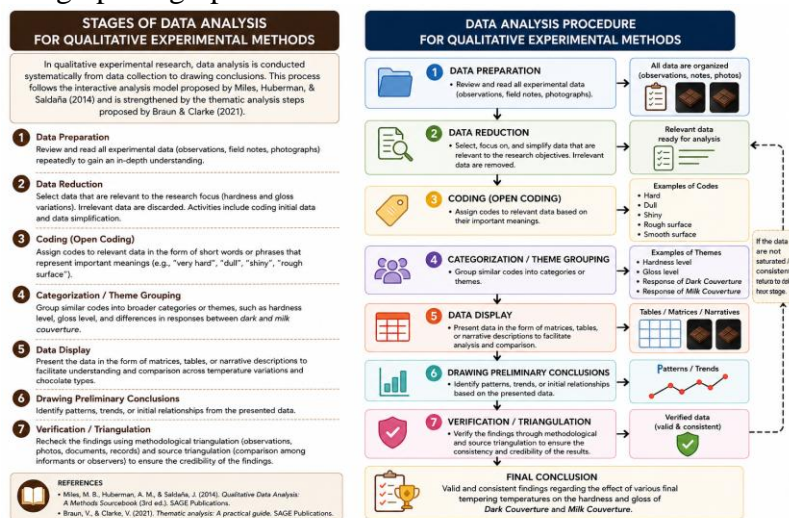


Figure 2. Stages of qualitative experimental data analysis

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Figure 2 shows that the data analysis did not move directly from observation to conclusion. The collected data were organized, reduced, coded, grouped into themes, displayed in tables and figures, and verified through comparison among observation notes and photographs. This procedure strengthens the credibility of the qualitative experimental findings ((Miles et al., 2014); (Braun & Clarke, 2021)).

RESULT AND DISCUSSION

The results are presented by separating dark couverture and milk couverture so that each product type can be interpreted according to its material characteristics. The main observation indicators were hardness, gloss, and surface condition. Photographs were used as visual evidence to support the observation results.

Table 6. Observation results and initial interpretation of dark couverture

Sample	Hardness	Gloss	Surface condition and interpretation
D28 (28°C)	Moderately hard. The sample showed more deformation than D30 and D32 when subjected to light mechanical disturbance.	Very glossy. The surface showed strong and relatively even light reflection.	The surface was smooth and clean with no visible blooming. The result indicates that 28°C produced the best visual gloss, although its mechanical resistance was lower than D32.
D30 (30°C)	Hard. The sample showed better resistance than D28 with only minor local deformation.	Glossy. The surface reflected light clearly, although gloss uniformity was slightly lower than D28.	The surface was stable and relatively smooth. This temperature produced a balanced response between hardness and gloss.
D32 (32°C)	Hard. The sample showed the highest mechanical resistance among dark couverture treatments.	Moderately glossy. The surface reflected light, but the gloss was lower and less uniform than D28 and D30.	The structure was mechanically stronger, but surface smoothness decreased slightly. This indicates that higher final temperature may increase hardness while reducing visual gloss.

Source: Processed by the Authors (2026)

Table 6 shows that dark couverture did not respond uniformly to all temperature variations. D28 produced the strongest visual gloss, but it did not provide the highest hardness. D30 showed a balanced hardness-gloss profile, whereas D32 showed the strongest resistance to deformation but lower surface gloss. This pattern indicates that the most visually attractive surface and the strongest mechanical structure were not achieved at the same final temperature. The result supports H1 and H2 because final tempering temperature affected both hardness and gloss qualitatively.



Figure 3. Dark couverture samples after final tempering temperature treatments
 Source: Processed by the Authors (2026)

Figure 3 supports the observation in Table 6. The visual documentation indicates differences in gloss, surface smoothness, and shape retention among dark couverture samples. The sample with stronger gloss showed a more reflective surface, while the sample with higher mechanical resistance appeared less glossy. These findings are consistent with the idea that tempering affects the physical properties of chocolate through changes in the organization of the fat structure ((Castro-Alayo et al., 2023); (Stobbs et al., 2025)).

Table 7. Observation results and initial interpretation of milk couverture

Sample	Hardness	Gloss	Surface condition and interpretation
M28 (28°C)	Hard. The sample showed the smallest deformation among milk couverture treatments.	Moderately glossy. Light reflection appeared but was not evenly distributed.	The surface was reasonably stable, although some uneven areas were visible. This indicates that 28°C produced good hardness but not the highest gloss.
M30 (30°C)	Moderately hard. Local deformation was more visible than M28.	Glossy. Light reflection was clearer and more even than M28.	The surface was relatively smooth with minor texture variation around the edge. This temperature produced a transitional balance between hardness and gloss.
M32 (32°C)	Soft to moderately soft. The sample showed the most visible deformation among milk couverture treatments.	Very glossy. The surface showed the strongest and most even light reflection.	The sample produced excellent surface gloss but lower structural firmness. This indicates that the final temperature improved surface appearance while reducing hardness.

Source: Processed by the Authors (2026)

Table 7 demonstrates a different pattern in milk couverture. Unlike dark couverture, M28 gave the strongest hardness, whereas M32 gave the highest gloss. This difference is scientifically reasonable because milk couverture contains milk components that can modify fat behavior, viscosity, and final texture. The findings indicate that a temperature

producing better surface gloss in milk couverture may not produce the highest hardness. This result supports H1 and H2, while also preparing the interpretation for H3.



Figure 4. Milk couverture samples after final tempering temperature treatments
Source: Processed by the Authors (2026)

Figure 4 shows that milk couverture samples had different visual responses from dark couverture samples. The surface of M32 appeared glossier, but the sample was less resistant to deformation. This means that surface appearance and mechanical stability should be evaluated separately. The interpretation is aligned with (Zarić et al., 2024), who showed that different chocolate types have different textural and thermal characteristics.

Table 8. Comparative response of dark and milk couverture

Temperature	Compared samples	Interpretation
28°C	D28 compared with M28	At 28°C, D28 showed stronger gloss, while M28 showed better hardness. This indicates that the same final temperature produced different dominant characteristics in the two types of couverture.
30°C	D30 compared with M30	At 30°C, both samples showed a relatively balanced response. D30 remained harder, whereas M30 showed improved gloss compared with M28. This temperature can be considered a transitional point for both couverture types.
32°C	D32 compared with M32	At 32°C, D32 showed the highest mechanical resistance among dark couverture samples, whereas M32 showed the highest gloss but lower hardness. This contrast supports the assumption that dark and milk couverture have different temperature responses.

Source: Processed by the Authors (2026)

Table 8 is central to answering the third research question and H3. The comparison shows that the same final tempering temperature did not produce identical physical responses in dark and milk couverture. Dark couverture tended to maintain firmer structure at higher temperature, whereas milk couverture gained higher gloss but lower hardness at 32°C. This confirms that the type of couverture must be considered when interpreting tempering results.

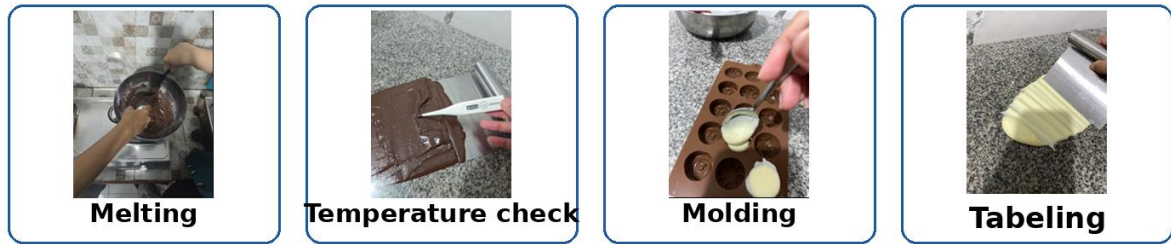


Figure 5. Experimental documentation of the tempering procedure
Source: Processed by the Authors (2026)

Figure 5 documents the experimental procedure, including melting, temperature measurement, molding, and mold release. This documentation strengthens methodological transparency because the physical results can be traced back to the treatment process. Consistent temperature recording and standardized molding are essential to ensure that differences among samples are related to final tempering temperature rather than uncontrolled handling differences.

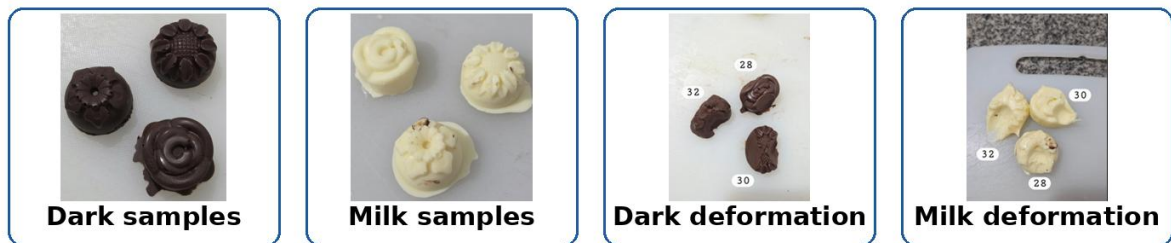


Figure 6. Comparative visual observation of dark and milk couverture samples
Source: Processed by the Authors (2026)

Figure 6 visually summarizes the comparison between dark and milk couverture. The dark samples generally showed stronger shape retention, especially at higher final tempering temperature. The milk samples showed stronger gloss at higher temperature but were more susceptible to deformation. The visual evidence supports the qualitative interpretation that material composition influences the response to tempering.

Table 9. Synthesis of findings, scientific meaning, and practical implications

Main finding	Scientific interpretation	Supporting references	Practical implication
Final tempering temperature affected hardness.	Different temperatures produced different levels of structural firmness and deformation resistance.	(Afoakwa, 2016);(Hartel et al., 2018)	Temperature control is needed to obtain consistent texture and mold release.
Final tempering temperature affected gloss.	Surface uniformity and light reflection changed across treatment temperatures.	(Castro-Alayo et al., 2023); (Stobbs et al., 2025)	Visual quality should be evaluated separately from hardness.
Some samples showed a trade-off between hardness and gloss.	The strongest sample was not always the glossiest sample.	(Ghazani & Marangoni, 2021); (Castro-Alayo et al., 2023)	Product targets should be defined before selecting the final tempering temperature.
Dark and milk couverture responded differently.	Cocoa butter, cocoa solids, sugar, and milk components influenced physical response.	(Zarić et al., 2024)	Final tempering temperature should be adjusted according to couverture type.
Observation and photographs were consistent.	Visual, tactile, and documentary data supported triangulated qualitative interpretation.	(Miles et al., 2014); (Braun & Clarke, 2021)	A standardized photo and observation protocol is useful for culinary laboratories.

Source: Processed by the Authors (2026)

Table 9 integrates the findings with scientific interpretation and practical implications. The analysis indicates that hardness and gloss must be treated as separate but related quality indicators. A sample can be visually glossy but mechanically weaker, or mechanically stronger but less glossy. This distinction is important for culinary and confectionery practices because product quality may prioritize different attributes depending on the intended use, such as praline shells, coating, decoration, or molded chocolate.

The findings are also consistent with the literature. (Castro-Alayo et al., 2023) and (Stobbs et al., 2025) showed that tempering affects crystallization and physical properties of chocolate. (Eriklioglu et al., 2025) emphasized that tempering and storage influence blooming and surface quality. In the present study, no direct claim is made regarding specific crystal forms because the experiment did not use crystallographic instruments. Instead, the discussion is limited to observable fat-structure stability, surface gloss, and tactile hardness. This wording keeps the interpretation scientifically cautious and methodologically consistent.

Based on H1, the observation results show that final tempering temperature affected chocolate hardness qualitatively. This is supported by differences in deformation and

resistance among D28, D30, D32, M28, M30, and M32. Based on H2, final tempering temperature also affected gloss, as indicated by differences in light reflection and surface uniformity. Based on H3, dark and milk couverture showed different responses to the same final tempering temperatures. Therefore, all working hypotheses were supported by the qualitative observation data.

NOMENKLATUR

Table 10. Research nomenclature

Term	Meaning
D28, D30, D32	Dark couverture samples treated at final tempering temperatures of 28°C, 30°C, and 32°C.
M28, M30, M32	Milk couverture samples treated at final tempering temperatures of 28°C, 30°C, and 32°C.
Blooming	White spots or whitish layers on the chocolate surface that may be associated with instability of fat, sugar, or storage conditions.
Stable fat structure	A conceptual observation term indicating a firmer, smoother, glossier, and visually stable chocolate surface based on qualitative observation.

Source: Processed by the Authors (2026)

CONCLUSION

Final tempering temperature variations affected the physical characteristics of dark couverture and milk couverture, particularly hardness and gloss. In dark couverture, 28°C produced the strongest gloss, 30°C produced a balanced hardness-gloss response, and 32°C produced the strongest mechanical resistance. In milk couverture, 28°C produced the highest hardness, 30°C produced a more balanced response, and 32°C produced the highest gloss but lower hardness. These patterns show that hardness and gloss do not always increase in the same direction. The comparison also confirms that dark and milk couverture respond differently to the same final tempering temperature. The qualitative experimental approach, supported by observation rubrics and photographic documentation, can be used as an initial evaluation method for tempering quality in culinary education laboratories and small-scale confectionery production. Future research should use repeated trials, texture analyzers, gloss meters, DSC, or image analysis to strengthen the qualitative findings with quantitative data

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the Department of Culinary Education, Faculty of Engineering, Universitas Negeri Jakarta, Indonesia, the academic supervisors, and all parties who supported the experimental process, observations, and photographic documentation in this research.

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