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Sensory Acceptability of Instant Noodles Cooked in a Calcium Oxide–Water Based Self-Heating Container: Effect of Reactant Proportion

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Abstract
Ready-to-eat (RTE) noodles require short but unavoidable cooking before consumption, which limits their convenience in situations without culinary facilities. A self-heating container utilizing the exothermic reaction between anhydrous calcium oxide (CaO) and water (H_2O) was developed to enable in-package cooking of instant noodles. This study evaluated the sensory acceptability of noodles cooked in a container using two reactant combinations. Noodles (60 g) cooked with 120 mL water were prepared in a single-shell container with the reactant chamber positioned below the product bowl. Two CaO:H_2O combinations, 125 g:75 mL (T8) and 150 g:75 mL (T11), previously identified as capable of attaining the target cooking temperature, were used to cook the product for six minutes; a conventionally cooked sample served as control. Color, flavor, body and texture, appearance, and overall acceptability were rated by a trained sensory panelist on a 9-point hedonic scale, and the data were analyzed using a Completely Randomized Design. The control group scored the highest for all attributes. T11 approached the control and scored significantly higher than T8 for color, body and texture, and appearance ($P<0.05$), while the flavor scores of the control, T8, and T11 were statistically comparable. T8 recorded the lowest scores, particularly for color (4.98 ± 0.51). Noodles cooked with the 150 g CaO:75 mL H_2O combination were rated as acceptable and closely comparable to conventionally cooked noodles, indicating the sensory feasibility of the self-heating container concept, although further design refinements are warranted.

Keywords: Exothermic reaction, calcium oxide, hedonic scale, ready-to-eat food, quick lime, product quality

1. Introduction

Changing lifestyles, urbanization, and the growing share of working women and nuclear families have fuelled the demand for ready-to-eat (RTE) foods in India. Instant noodles are one of the most widely consumed RTE products; however, unlike many other RTE items, noodles require a brief but unavoidable cooking step before consumption. This requirement limits consumer groups such as travellers, campers, and students who lack access to culinary facilities, partly negating the convenience that RTE foods are expected to offer (Raziuddin et al., 2024; Adil et al., 2024) [2]. The development of self-heating food packaging represents an important advancement in active food packaging technology, as it integrates heat generation directly within the package. Such systems eliminate the need for external cooking equipment, electricity, or fuel, thereby enhancing product convenience in situations where conventional food preparation facilities are unavailable. Self-heating packages have attracted increasing interest for military rations, emergency relief foods, outdoor recreation, travel, and institutional food services because they provide consumers with hot meals under diverse environmental conditions (Brody, 2002; Robertson, 2016) [4, 10]. Among the different heat-generation technologies investigated, exothermic chemical reactions are considered the most practical for disposable food packages because they are compact, inexpensive, and capable of producing rapid heat without external energy input. Calcium oxide reacts vigorously with water to release considerable amounts of heat, making it one of the most widely investigated reactants for self-heating food containers. Furthermore, calcium oxide is inexpensive, readily available, and recognized as safe for indirect food-contact applications when appropriately isolated from the food compartment (Brody, 2002) [4].

Although several self-heating package designs have been reported in patents and engineering studies, comparatively few investigations have evaluated the sensory qualities of foods prepared using these systems. Instrumental measurements, such as temperature profiles, heat generation, and heat transfer efficiency, provide valuable information regarding package performance; however, consumer acceptance ultimately depends on sensory attributes such as color, flavor, texture, and overall acceptability. Therefore, sensory evaluation remains an essential criterion for assessing the practical feasibility and commercial potential of self-heating food packaging systems (Stone & Sidel, 2012; Lawless & Heymann, 2010) [12, 6].

Self-heating packaging, in which an exothermic chemical reaction embedded within the container supplies the heat needed to warm or cook food, has been explored internationally, predominantly through patent literature, with very limited peer-reviewed reporting. A review of the available literature further indicated that most reported self-heating systems were designed merely to warm food to approximately 70–75 °C rather than to cook it at temperatures near 80–85 °C, and no related work originating from India was found (Bohra et al., 2015) [3]. Calcium oxide, good reactant with water its Generally Recognized as Safe (GRAS) status, and its established use as a permitted food additive, was identified as a suitable reactant for this purpose. While the thermal performance of such containers, heat generation, heat transfer, and overall heat transfer coefficients can be characterized instrumentally, the ultimate acceptability of the cooked product depends on its sensory quality. This aspect has received little attention in the literature on self-heating packaging. Therefore, the present study was undertaken to evaluate the sensory characteristics of instant noodles cooked using a lab-scale self-heating container, comparing the product cooked with two reactant combinations against conventionally cooked noodles.

2.0 Materials and Methods

2.1 Materials

Dry instant noodles from a popular commercial brand were procured from the local market. Anhydrous calcium oxide (CaO), a white crystalline compound also known as quicklime, was obtained from a local market. Membrane-filtered (RO) drinking water available at the institute was used for both noodle cooking and for hydration of CaO.

2.2 Optimization of Dry Noodle to Cooking Water Ratio

Preliminary trials were conducted to standardize the dry noodle to cooking water ratio. Mixtures of dry noodles and water in the proportions 1:1.0, 1:1.5, 1:2.0, 1:2.5, and 1:3.0 were cooked conventionally and evaluated for overall acceptability using a 9-point hedonic scale (Peryam & Pilgrim, 1957; Stone & Sidel, 2012) [12]. The best-performing ratio was subsequently used for all further trials involving the self-heating container.

2.3 Container design and reactant combinations

A single-shell stainless-steel container (Design-2) with a horizontal partition was used, comprising a lower heating chamber charged with CaO and an upper product bowl holding the noodles and cooking water; the base of the product bowl also served as a heat-transfer surface. A needle-type trigger released a measured quantity of water onto the CaO to initiate an exothermic reaction. This design was previously found to be superior to an alternative concentric cylinder design (Design-1) in terms of the rate and extent of temperature increase; therefore, it was selected for sensory evaluation trials. Among the CaO:H_2O combinations screened for their ability to raise the product-side temperature to the target cooking temperature of approximately 85 °C within six minutes, two combinations, 125 g CaO with 75 ml H_2O (T8) and 150 g CaO with 75 mL H_2O (T11), were found to be the most suitable and were carried forward for cooking and sensory evaluation of the noodles (Searle and Richardson, 2003) [11].

2.4 Cooking procedure

For each trial, 60 g of dry noodles were cooked with 120 ml of water in the product bowl of the container. The reaction was initiated by activating the trigger, and cooking was allowed to proceed for six minutes. A control sample with the same quantity of noodles and water was cooked conventionally by boiling. All the cooked samples were served hot in identical noodle bowls to the sensory panel.

2.5 Sensory Evaluation

The sensory evaluation was performed in two stages. In the first stage, only the overall acceptability was assessed to optimize the dry noodle to water ratio. In the second stage, noodles cooked with the T8 and T11 reactant combinations, along with the conventionally cooked control, were evaluated by a trained panel of judges for color, flavour, body and texture, appearance, and overall acceptability using a 9-point hedonic scale, where 9 denoted “extremely liked” and 1 denoted “extremely disliked.” Each trial was replicated at least three times to obtain the mean scores (Stone and Sidel, 2012) [12].

2.6 Statistical Analysis

Sensory data obtained from the final screening and cooking performance trials were analysed statistically using a Completely Randomized Design to identify significant differences among treatments. Means bearing different superscripts within a row/column were considered significantly different at the 5% level of significance (Montgomery 2017) [8].

3.0 Results and Discussion

3.1 Optimization of dry noodle to cooking water ratio

The sensory scores obtained for the overall acceptability of the tested dry noodle to water ratios are presented in Table 1. The 1:2.0 ratio recorded the highest mean acceptability score, followed by 1:2.5, for the 60 g noodle sample evaluated in this experiment, the 1:2.0 ratio recorded the highest mean overall acceptability score, followed by the 1:2.5 ratio. Ratios with proportionally less water (1:1.0 and 1:1.5) or more water (1:3.0) were rated lower. Accordingly, a sample size of 60 g dry noodles with 120 ml cooking water (1:2.0) was fixed for all subsequent trials involving the self-heating container. This result may be interpreted as indicating that the 1:2.0 ratio provided a suitable balance between water availability, texture, and overall eating quality; however, starch hydration and residual free water were not measured directly in this study. This standardized cooking ratio was subsequently adopted for all thermal performance and sensory studies to eliminate variations arising from differences in cooking water and to allow meaningful comparisons among the reactant combinations. The data mentioned in Table 1 were analysed using a completely randomized design; however, statistical significance among the ratios was not determined because the preliminary screening was based primarily on mean sensory scores.

Table 1: Effect of dry noodle to cooking water ratio on overall acceptability, shown for the 60 g noodle series

Dry noodle : water ratio	Weight of noodle (g)	Volume of water (ml)	Mean sensory score ± SD
1 : 1.0	60	60	3.20 ± 0.748
1 : 1.5	60	90	4.60 ± 1.020
1 : 2.0	60	120	7.60 ± 0.800
1 : 2.5	60	150	6.80 ± 0.748
1 : 3.0	60	180	4.20 ± 0.748

Note: (data represent mean ± SD; n = 3 replicates per treatment).

3.2 Sensory quality of noodles cooked in the self-heating container

The sensory scores obtained for the noodles cooked with T8 (125 g CaO + 75 mL H_2O) and T11 (150 g CaO + 75 mL H_2O) combinations, along with the control, are presented in Table 2.

Table 2: Sensory evaluation of noodles cooked in the self-heating container

Sensory attribute	T0 (Control)	T8 (125 g CaO + 75 ml H2O)	T11 (150 g CaO + 75 ml H2O)
Colour	7.75 ± 0.45^{a}	4.98 ± 0.51 ^{c}	6.66 ± 0.65 ^{b}
Flavour	7.66 ± 0.49 ^{a}	6.58 ± 0.51 ^{b}	7.41 ± 0.66 ^{a}
Body and texture	7.83 ± 0.38 ^{a}	6.72 ± 0.45 ^{c}	7.00 ± 0.85 ^{b}
Appearance	7.73 ± 0.38 ^{a}	6.21 ± 0.51 ^{c}	7.16 ± 0.57 ^{b}
Overall acceptability	7.91 ± 0.28 ^{a}	6.91 ± 0.51 ^{b}	6.96 ± 0.38 ^{c}

Data are presented as mean ± SD (n = 3); means bearing different superscripts within a row differ significantly at the 5% level of significance.

The color scores of the experimental samples differed significantly from those of the control. Sample T11 (6.66 ± 0.65) scored significantly higher than T8 (4.98 ± 0.51) but remained significantly lower than the control (7.75 ± 0.45), and the T8 sample appeared visibly dull. In contrast, flavour scores of the control, T8 and T11 were statistically at par with one another, indicating that the flavour of the noodles was not significantly affected by cooking in either reactant combination relative to conventional cooking.

For body and texture, appearance, and overall acceptability, the control recorded the highest scores, followed by T11, with T8 recording the lowest scores for all three attributes; the differences among all three samples were statistically significant. Based on the overall acceptability scores, the control was rated as "extremely liked," the T11 sample was rated as "liked very much," and the T8 sample was rated as merely "liked." The comparison indicated that T11 approached, but did not statistically equal, the sensory quality of conventionally cooked noodles, whereas T8 trailed behind both T11 and the control.

The comparatively poorer performance of T8 may be attributed to insufficient and less sustained heat generation relative to that of T11, resulting in uneven cooking of the noodles. Flavour and appearance scores were generally better than color and overall acceptability scores across the experimental samples; this may be linked to the dull color of the noodles cooked in the container, which likely influenced overall acceptability, along with possible effects of the six-minute heating duration on the product. These sensory findings are consistent with the observation that of all treatment combinations screened, T11 (150 g CaO:75 ml H2O) achieved the earliest and most sustained temperature rise above the 85 °C cooking benchmark, providing a plausible thermal basis for its comparatively better sensory performance relative to T8. The absence of significant differences in flavour suggests that the exothermic heating system itself did not impart undesirable sensory notes to the product because the reactants remained physically isolated from the food compartment. Consequently, flavour development primarily depended on the commercial seasoning formulation rather than the heating method.

3.3 Relationship between thermal performance and sensory attributes

Previous engineering trials on the same self-heating-container showed that the single-shell- design with a horizontal partition (Design-2) and the reactant combination of 150 g CaO + 75 mL H_2O (T11) achieved higher and more sustained product-side- temperatures than alternative designs and reactant ratios. The average overall heat transfer- coefficients for the two most promising combinations (125 g CaO + 75 mL H_2O and 150 g CaO + 75 mL H_2O) were reported to be approximately 415–460 W/m²·K, with T11 reaching and maintaining temperatures above the cooking benchmark of approximately 85 °C more consistently. The present sensory results mirror this thermal behaviour: treatment with stronger and longer heat delivery (T11) produced noodles with better body, texture, and appearance than T8, indicating that both peak temperature and time at near-boiling- conditions strongly influence the structural development and visual quality of instant noodles cooked in the self-heating- container.

The optimization of the dry noodle to cooking water- ratio to 1:2.0 in Section 3.1 ensured that sufficient water was available for starch gelatinization without leaving excessive free water after cooking, which would otherwise increase evaporation losses and dilute flavour. Earlier analytical and experimental estimates of cooking heat requirements in this thesis showed that using more than twice the noodle mass in water leads to higher actual heat demand because excess free water evaporates and removes latent heat during cooking. When combined with the present sensory findings, this suggests that successful in-container- cooking in a self-heating- system requires simultaneous optimization of (i) reactant–water proportions for adequate heat generation, (ii) product–water ratio for efficient heat utilization, and (iii) container geometry for effective heat transfer to the food compartment.

3.4 Comparison with published instant noodle studies

The hedonic scores obtained for the control and T11 samples were comparable to those reported in formulation studies on instant noodles produced from composite flours and enriched ingredients. For example, instant noodles formulated from sweet potato–soybean–corn flour blends typically achieve mean scores of approximately 6–7 for texture, flavor, appearance, and overall acceptability on a 9-point scale when considered optimized. Similarly, noodles enriched with seaweed or climate-resilient crops often receive overall acceptability scores in the 5–6 range on 9-point hedonic scales, corresponding to “like moderately” to “like very much.” In the present study, the conventionally cooked control scored close to the upper end of this range for all attributes, while T11 reached approximately 7.0 for body, texture, and appearance, and nearly 7.0 for overall acceptability, indicating strong acceptance comparable to many successful instant noodle formulations despite being cooked in a non-traditional self-heating- system (Adebayo et al., 2018; Koh et al., 2022; Lekjing and Venkatachalam, 2022) [1, 5, 7]. In contrast, the T8 treatment, with a color score below 5 and slightly lower scores for body, texture, and overall acceptability, was near the threshold of acceptability documented for some high-substitution- composite noodles. Studies on Musa spp–wheat composite noodles and green banana starch-enriched-- noodles show that when formulation or processing conditions reduce color or texture quality, overall acceptability can decline from “like moderately” towards “dislike slightly,” even if the taste remains acceptable. The present sensory pattern is similar: the dull color and less favorable texture of T8 lowered overall acceptability compared with T11 and the control, underlining that visual and textural attributes are more sensitive to heating regime than flavor, which was largely determined by the commercial seasoning and remained statistically unchanged across the treatments.

4.0 Conclusion
The dry noodle to cooking water ratio of 1:2.0 was found to be the most acceptable for instant noodles based on sensory evaluation. Noodles cooked in a self-heating container using the exothermic reaction between CaO and water were rated as acceptable, although sensory scores for color, body and texture, appearance, and overall acceptability remained significantly lower than those of conventionally cooked noodles for both reactant combinations tested. Between the two combinations, 150 g CaO with 75 mL H_2O (T11) produced noodles that were closer in sensory quality to the control and were rated as liked very much, whereas 125 g CaO with 75 ml H_2O (T8) produced comparatively poorer color and texture and was rated as liked. Flavour was not significantly affected by either reactant combination relative to conventional cooking. These findings indicate that in-package exothermic cooking of noodles using CaO and water is sensorially feasible; however, further modification of the container design and reactant proportioning is required to bring the product quality closer to that of conventionally cooked noodles before commercial application.

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