Designing Internal Structure of Chocolate and Its Effect on Food Texture

Yujin Lee *
KAIST, Industrial Design Dept
Dajeon, 34134, South Korea
neaj0812@kaist.ac.kr

Jee Bin Yim *
KAIST, Industrial Design Dept
Dajeon, 34134, South Korea
jeebiny@kaist.ac.kr

Daye Kang
KAIST, Industrial Design Dept
Dajeon, 34134, South Korea
dayekang@kaist.ac.kr

HyeonBeom Yi
KAIST, Industrial Design Dept
Dajeon, 34134, South Korea
roetry@kaist.ac.kr

Daniel Saakes
KAIST, Industrial Design Dept
Dajeon, 34134, South Korea
saakes@kaist.ac.kr

* Both authors contributed equally to this article.

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Abstract
Food texture is one of the important factors of eating experience. An internal structure of food makes a difference in food texture. In this research, we explored the effects of the internal structure on the texture of chocolate by designing, building, and testing chocolates with different internal structures and internal chocolate percentage. Multiple layers of patterned chocolate were stacked as a fabrication method. Each layer was fabricated using a silicone mold that was made using a 3D printed model. We created seven types of chocolate variations through this system. Fourteen university students participated in the preliminary user test. We found out that the internal structure and the chocolate ratio affects the perceived 'hardness' of the chocolate.

Author Keywords
Digital Gastronomy; Food Texture; Internal Structure; Mold; Chocolate; Food fabrication;

CSS Concepts
Human-centered computing~Human computer interaction (HCI)

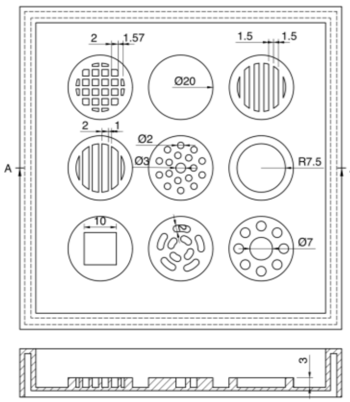

Figure 1: Considering the limits of mold making resolution and the direction of chocolate's inner structure, we chose the final pattern.

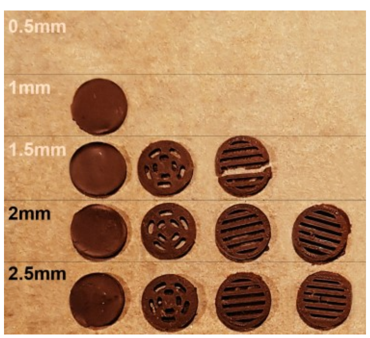

Figure 2: A silicone mold with thickness from 0.5 mm to 2.5 mm at intervals of 0.5 mm was used to find the appropriate layer thickness.

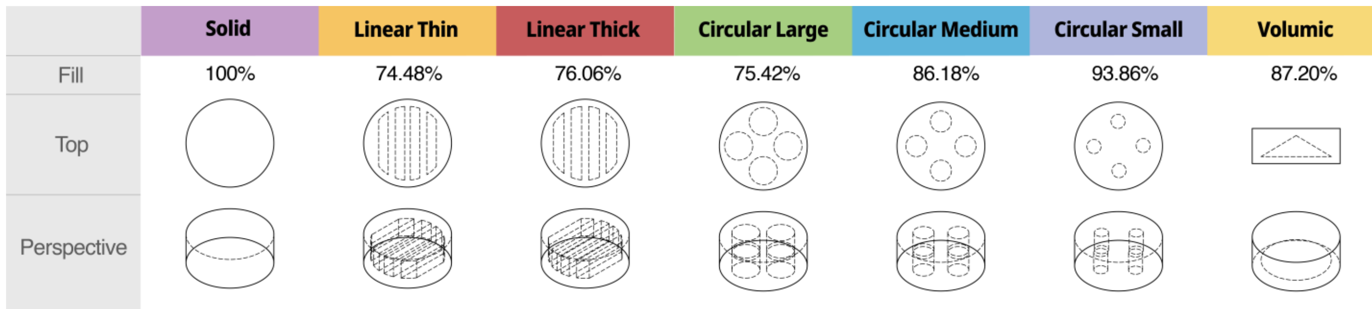

Figure 3: The final pattern variations: Linear Thin, Linear Thick, Circular Large, Circular Medium, Circular Small, and Volumic.

Introduction

A growing number of researches are being conducted in the area of food fabrication. Machines such as food 3D printers [4] and Formbox [7] were developed to help non-professional individuals to create sophisticated food structures. Moreover, other researches suggested cooking processes that utilize designing tools like stamp [3] or mold [2] to lower the degree of difficulty in cooking. Researches have been done to measure the food texture of the digitally fabricated foods [9, 12]. Existing papers are focused on predicting the texture of food based on experiments on chocolate’s material property such as its melting properties and compression/ shear strength [11]. However, the food texture cannot simply be explained by ingredients’ materiality [5]. In this article, we wanted to focus on investigating how people perceive food texture.

In this research, we wanted to focus on investigating the user’s eating experience and how it is influenced by the food texture. We decided to focus on the internal physical structure because it is one of the key factors that determine the food texture [1]. For easy and fast fabrication, we implemented a mold system instead of a 3D-printer [8]. The structure built by stacking different patterns of layers. We choose chocolate, one of the most popular semi-solid food, as an ingredient for the study since it is easily obtainable and moldable. It has a low melting point (30 degrees Celsius) and exists in a solid state at room temperature.

Using chocolate and the molding system, we designed seven pattern variations with different structure and internal chocolate percentage (chocolate ratio). Then we conducted a preliminary study with 14 participants to examine how internal structures influence people’s perceived food texture and eating experience. The results of the questionnaires and interviews confirmed that the chocolate ratio and the internal structure affects perceived ‘hardness’ of the chocolate and overall food experience.

Design

We wanted to know how the texture changed according to the internal structure of the chocolate. Therefore, we proposed a method to make chocolate variations with the same exterior but has different internal structures

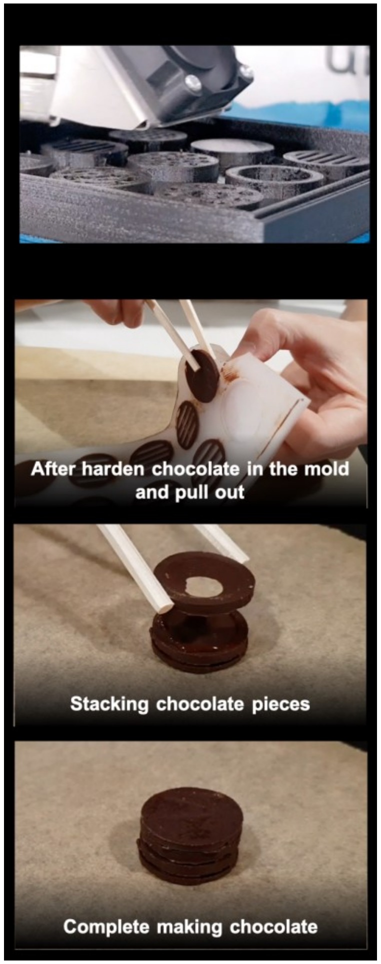

Figure 4: Chocolate making process.

using a mold and a single ingredient, chocolate. Overall, the circular shape with no angular parts was selected to easily remove the chocolate from the mold.

Through multiple testing with four versions of mold, we found an ideal mold shape. We also experimented to find the optimal temperature and chocolate type. Finally, we decided to melt chocolate in 36 degree Celsius and use chocolate which is a 1:1 mixture of two types of plain chocolate with a cacao ratio of 56% and 72%.

Pattern Design

While designing the internal structure, we considered the shape, dimension, and direction of the patterns. After trying several patterns (Figure 1), we designed two linear, three circular, one volumic, and one solid pattern variations (Linear Thin, Linear Thick, Circular Large, Circular Medium, Circular Small, and Volumic).

Layer Thickness

After multiple testing, we discovered that chocolates were easily removable from the mold when it was 2 mm and thicker (Figure 2). Therefore, we decided to make the layers 2 mm thick, (except for the Volumic pattern). The size of the assembled chocolate was 25 mm in diameter, 10 mm in height, and consist of 5 layers including the solid top and bottom layer.

Chocolate Making Process

After the patterns were created using Fusion360, it was printed using a 3D printer. The 3D printed mold was then used to cast a silicone mold. Carefully tempered and hardened chocolate layers were removed from the mold [10]. The pattern layers were assembled with the top and bottom solid layer to complete the chocolate making process.

Preliminary User Test

With the created chocolates we conducted a preliminary user test to investigate the effects of chocolate inner structures on people's eating experience. Total of 14 university students participated in the test, which took approximately 20 minutes (N = 14, Average age = 25.9). Each participant randomly ate three of the seven chocolate variations with different internal structures and chocolate ratios. After eating each chocolate, they were asked to answer the Food Texture Questionnaire. Questions 1 to 9 were adopted from Kohei et al [6]. to measure the chocolate hardness in the 5 point Likert scale. Loosely structured interviews were also conducted asking the participants to describe the chocolate "feeling" and compare 3 different variations that they have tasted.

Question 1	How hard was it to break the food down in the mouth?
Question 2	How pleasant was the food in the mouth?
Question 3	How tasty was the food?
Question 4	How thin was the food in the mouth?
Question 5	How easy was it to swallow the food?
Question 6	How was the pharyngeal clearance?
Question 7	How much did you chew?
Question 8	How easy did the food gather in the mouth?
Question 9	How sticky did it feel in the mouth?

Table 1: We adopted the Food Texture Questionnaire questions from Kohei et al. to measure hardness of the chocolate [6].

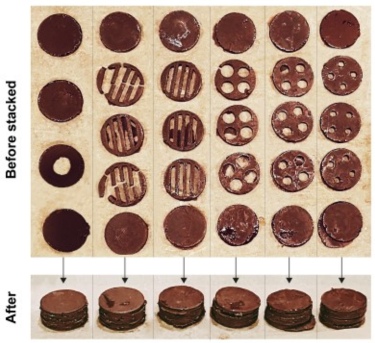

Figure 5: Assembled chocolates.

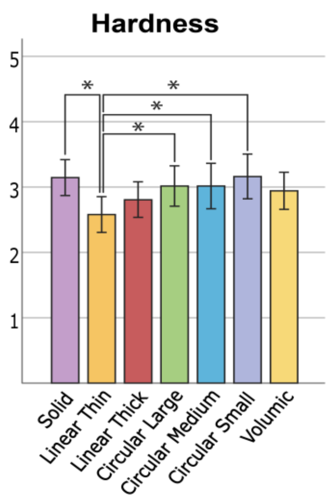

Figure 6: Results of the ANOVA test that compared the perceived "hardness" between the variations.

Result

Questionnaire

In total, 42 questionnaires were answered by the participants, 6 for each of chocolate patterns. We performed a Linear Regression Analysis, and the results showed a strong correlation between the chocolate ratio and hardness (R-squared value = 0.72). This demonstrates that as the chocolate ratio of the variation increases, the perceived hardness of the chocolate also increased.

Moreover, we used ANOVA test to compare the perceived "hardness" between the variations. There was a statistically significant difference between Linear Thin and Solid, Circular Large, Circular Medium, and Circular Small (Figure 6). Even though Linear Thin (74.48%), Linear Thick (76.06%), and Circular Large (75.42%) has a similar chocolate ratio, only Linear Thin and Circular Large had a significant difference. This shows that the pattern of inner structure also influences the chocolate texture along with the ratio.

Interview

Participants were asked to describe their eating experience during the loosely structured interviews. We discovered that the participants could easily differentiate(not identify) the chocolates with different patterns and compare their textures.

"I could feel the structures. It was light, and I liked feeling of hollow spaces." (P10)

"Felt like there were layers." (P14)

Plus, they used words like sticky, pasty, crispy, fresh, heavy, and bitter to explain their experience.

"It is relatively hard and most sticky (out of 3 variations). I can still taste it in my mouth." (P02)

Conclusion and Future Work

In this paper, we suggested a method of food fabrication using a mold system to device chocolates with different internal structures. Our study also investigated whether the difference in internal structures causes people to have different food texture experience. The results of the questionnaire and interviews confirmed that the participants' perceived "hardness" were affected by the internal patterns and chocolate ratio.

Furthermore, the result of our preliminary test showed that the internal structure of chocolate affects not only the textural experience but it is also used to perceive its structure and flavor. When the research is further developed, its findings could be applied to other food fabrication process to control and design food's perceived texture such as crispiness, pastiness, solidness, and so on. In the future, one might be able to use an identical amount of the same ingredient to fabricate food that has different food textures, flavor, and even satiety.

The next step of our research would be to expand the scope of the study to include other food textures such as cohesiveness, adhesiveness, and springiness. The internal structures and its mold patterns should also be diversified to test a broader range of chocolate ratio and textures. In future user testing, we would like to include a larger number of participants and involve them in the designing and assembling process to test the customization aspect of the research.

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