Thesis for the Degree of Master of Engineering

Physicochemical and Sensory Characteristics of Gluten-Free Noodles Added with Chicken Breast Meat

by

Chae Hyeon Lee

Department of Food Science & Technology

The Graduate School

Pukyong National University

February 2023

Physicochemical and Sensory Characteristics of Gluten-Free Noodles Added with Chicken Breast Meat

닭가슴살을 첨가한 글루텐 프리 면의 물리화학적 및 감각적 특성

Advisor: Prof. Suengmok Cho

by

Chae Hyeon Lee

A thesis in partial fulfillment of the requirements

for the degree of

Master of Engineering

In Department of Food Science & Technology, The Graduate School, Pukyong National University

February 2023

Physicochemical and Sensory Characteristics of Gluten-Free Noodles Added with Chicken Breast Meat

A dissertation

by

Chae Hyeon Lee

Approved by:

(Chairman) Young-Mog Kim

(Member) Yang-Bong Lee

(Member) Suengmok Cho

February 17, 2023

Contents

List of Tables

List of Figures

글루텐프리 닭가슴살 면의 물리화학적 및 감각적 특성

이 채 현

부경대학교 대학원 식품공학과

요 약

최근 닭가슴살(Chicken breast meat, CBM)은 영양가치가 높고 가격도 저렴하여 떠오르는 웰빙 식품이다. 한편, 밀가루 국수(Wheat noodle, WN)의 주요 단백질인 글루텐은 밀가루 식품 특유의 식감 형성에 큰 영향을 주지만, 알레르기, 면역질환 등의 건강문제를 유발한다. 본 연구에서는 전분 종류에 따라 CBM을 첨가한 글루텐 프리 면의 물리화학적 및 관능적 특성을 조사하였다. WN에 비해 CBM을 첨가한 면(CN)은 경도를 제외한 관능 특성이 모두 낮았다. CN 중에서는 CN-T가 WN과 가장 유사한 관능 특성을 보였다. CN의 색상은 CBM에 함유된 미오글로빈으로 인해 WN보다 명도가 낮고 적색이 높게 나타났다. 물성 특성에서 CN의 경도와 접착성은 WN과 유의한 차이가 있었다. 특히 CN-T의 접착력은 WN과 유사하였고, CN-S의 응집력은 WN보다 유의적으로 낮았다. WN에 비해 CN-P가 더 높은 수분흡수력을 보인 반면 유사한 볼륨증가율을 보인 것은 물성에서 CN-P의 경도가 WN보다 유의적으로 높았던 것을 설명하기에 충분했다. CN의 내부구조에서 ungelatinized region이 발생했으며, WN보다 구조적으로 결합력이 좋지 않아 접착력이 증가하였다. 이는 전반적 기호도에 부정적인 영향을 미쳤다. CN 중 기호도가 가장 높았던 CN-T는 WN보다 높은 단백질 함량과 낮은 탄수화물 함량을 보였다. 이러한 결과는 글루텐 프리 면을 제조하기에 CBM을 첨가하는 것이 영양적, 감각적으로 적절함을 시사한다.

Introduction

Chicken meat is one of the most popular edible meats worldwide. It is recently consumed more in the form of part meat such as thigh, breast, drumstick, and wings rather than whole chicken (Ha et al., 2019). Among the partial meats of chicken, chicken breast meat (CBM) has been the least popular part because it has a low sensory acceptance of fleshiness and juiciness (Kyarisiima et al., 2011; Shi et al., 2020). However, CBM is a nutritionally excellent foodstuff with high-protein and low-fat contents than other partial chicken meat (Koh & Yu, 2015). As consumers became interested in health in recent years, CBM has been considered to be a well-being foodstuff (Kim, 2019). Now, CBM has been processed in various food types such as jerky, steak, and sausage (Brambila et al., 2017; Choi et al., 2016; Jo et al., 2018; Nam et al., 2017). However, commercial noodles added with CBM, and studies on them are few (Kim & Kim, 2009).

Wheat flour is the representative ingredient used in various noodles (Landillon et al., 2008). Gluten protein is abundant in wheat flour, which consists of 80-85% of the wheat flour protein (Wieser, 2007). Gluten plays a key role in forming the unique texture properties of processed wheat flour noodles, by conferring water absorption capacity, viscosity, cohesivity, and elasticity on the dough (Veraverbeke & Delcour, 2002; Wieser, 2007). As people have certain health conditions or get older, intake of gluten can cause health problems, such as wheat allergy, autoimmune, and immune-mediated diseases (Aronsson et al., 2015; Sapone et al., 2012). For this reason, a lot of researchers have conducted studies on wheat flour substitutes for the development of gluten-free products (Gao et al., 2018; Violalita et al., 2020; Xu et al., 2020). In previous studies, animal proteins (egg white and chicken powder) and vegetable proteins were investigated for the production of gluten-free noodles (Guo et al., 2020; Oyeniran et al., 2021; Violalita et al., 2020). Nevertheless, CBM has been not yet considered as a main ingredient for gluten-free noodles.

In this study, we investigated the application potential of CBM as a main ingredient for gluten-free noodles. The physicochemical and sensory characteristics of CBM noodles (CN) were compared to wheat flour noodle (WN). The physicochemical properties of noodles were evaluated by observing their texture profiles, water absorption capacity, volume expansion ratio, color values, and proximate composition.

Materials and Methods

1. Materials

Frozen CBM (Hanssem General Food, Gwangju, Korea), wheat flour (CJ Cheiljedang Corp., Seoul, Korea), tapioca starch (Daemyung FM, Pocheon, Korea), potato starch (Chungeun F&B, Goyang, Korea), sweet potato starch (Donga food, Ulsan, Korea) were used for preparing noodles. Eggs were purchased at the local market (Busan, Korea) and the yolk was separated and used. All reagents and chemicals used in the experiments were analytical grades.

2. Preparation of noodles

Frozen CBM was thawed in the refrigerator for a day and washed twice in running water. The washed CBM was ground using a silent cutter for 15 min. As shown in Table 1, three CBM noodles (CN) were prepared by the addition of different starches (tapioca starch, T; potato starch, P; and sweet potato starch, S). Due to the high moisture content of CBM, water was not added to CNs. The wheat flour noodle without CBM was prepared as a control. The mixed raw materials of each sample were kneaded for 5 min using a kneader, made into one lump, and refrigerated overnight. After that, the final dough was made to a thickness of 1.4 mm over six stages using a pasta machine. The thinly spread dough was cut to 7.0 mm in width and stored frozen at -20℃. The frozen noodles were boiled in 20 times water per g for 9 min and then cooled in running

Table 1. Formula for preparation of chicken breast meat noodles (CN) and wheat flour noodle (WN)

Ingredients	Amount (g)			
	WN	CN-T	CN-P	CN-S
Wheat Flour	300			
Starch		150	150	150
CBM		150	150	150
Water	115			
Yolk	20	20	20	20
Total	441	326	326	326

CBM, chicken breast meat; T, tapioca starch; P, potato starch; S, sweet potato starch.

water for 1 min, left for 5 min, and used in the experiment (Figure 1). The mixing ratio of noodles was determined by the maximum content of CBM that could form noodles through a preliminary experiment.

3. Proximate compositions

The proximate compositions of cooked CN-T and WN were measured using standard analysis methods (AOAC, 2003). The moisture content was determined by the oven-drying method. The crude lipid content was measured via Soxhlet extraction, the crude protein content was measured using the micro-Kjeldahl method, and the ash content was measured by the dry-ashing method. The total carbohydrate content was calculated by the following equation: Total carbohydrate content (%) = 100 – (moisture content + lipid content + ash content + protein content). All analyses were performed in triplicate and expressed as mean ± SD.

4. Colors

The international commission on illumination (CIE) $L^*a^*b^*$ colors of uncooked and cooked noodles were measured using a colorimeter (TES-135A, TES Co., Taiwan). The colors of the uncooked noodles were measured in the state of thinly spread dough, and the colors of the cooked noodles were measured by arranging three strands of cooked noodles side by side in parallel. The colors were evaluated as L^* (lightness), a^* (red-green), and b^* (yellow-blue) values.

Figure 1. Appearance of cooked chicken breast meat noodles (CN) and wheat flour noodle (WN). T, tapioca starch; P, potato starch; S, sweet potato starch.

The L^*, a^*, and b^* values of the calibration plate were 94.62, -0.780, and 1.362, respectively. The colors of noodles were measured 10 times repeatedly and expressed as mean ± SD.

5. Water absorption capacity and volume expansion ratio

Water absorption capacity (WAC) of noodles was determined by the weight of the noodles (Oh et al., 1985). The uncooked and cooked noodles were weighed, and WAC was calculated by the following equation: Water absorption capacity (%) = (weight of cooked noodles – weight of uncooked noodles) ÷ (weight of uncooked noodles) × 100.

The volumes of the noodles were measured by filling a 500 mL mass cylinder with 300 mL of distilled water, and then adding the noodles before and after boiling. Volume expansion ratio (VER) was calculated by the following equation: Volume expansion ratio (%) = (volume of cooked noodles) ÷ (volume of uncooked noodles) × 100.

6. Texture properties

The texture properties were determined using a texture analyzer (Model CR-100D, Sun Scientific Co., Ltd., Tokyo, Japan), and hardness, springiness, cohesiveness, and adhesiveness were analyzed. The cooked noodles were compressed to 1.2 mm with a 2 kg load cell at mode 20 and a speed of 60 mm/min. The hardness of noodles was subjected to a one-cycle compression with probe No. 1 (Ø 5 mm). The springiness, cohesiveness, and adhesiveness of noodles were subjected to a two-cycle compression with probe No. 25 (Ø 10 mm). Four samples were prepared individually and tested for each sample.

7. Low-vacuum scanning electron microscope

To investigate the effect of the addition of CBM to noodles and starch substitution through microstructure, low-vacuum scanning electron microscope (LV-SEM) of noodles was observed. The cooked noodles were cut into a length of 50 mm, frozen overnight at a deep temperature of -80℃ without sticking to each other, and freeze-dried for 48 hours using a freeze dryer (Hypercool HC4110, Gyrozen Co. Ltd., Daejeon, Korea). The freeze-dried sample was coated with a gold layer using an ion sputter coater (Hitachi, E-1010, Tokyo, Japan), and observed by LV-SEM (JSM-6490LV, JEOL Ltd., Tokyo, Japan) operating at 15 kV.

8. Sensory properties

The sensory evaluation was conducted by 15 members panels of trained professionals (Gender: 5 males and 10 females, Age: 21-32 years), belonging to the Department of Food Science and Technology at Pukyong National University. To manufacture the samples for sensory evaluation, a seasoning solution was prepared by dissolving commercially available Kkokko noodles powder in cold water at 1:4 (w/w), and cooked noodles and seasoning solution were mixed at 4:1 (w/w). The samples were used at a temperature of 20℃ or less and evaluated in terms of intensity of hardness and chewiness, and preference of appearance, taste, and overall acceptance. The sensory evaluation was performed on a 9-point hedonic scale (1 point: very bad or weak, 5 points: not bad or weak, 9 points: very good or strong).

9. Statistical analysis

All results were analyzed using GraphPad Prism 8.0 (Graphpad Software, Inc., San Diego, CA, USA). The significant difference test between mean values was analyzed by one-way analysis of variance (ANOVA), and the post-analysis was conducted through Tukey's multiple comparisons test. For multiple comparisons in proximate composition, the data were statistically assessed using multiple unpaired t-tests and Holm-Sidak method.

Results and Discussion

1. Sensory properties

Sensory characteristics of three CNs and WN were evaluated in five evaluation items (overall acceptance, appearance, taste, hardness, and chewiness) (Figure 2A) and relationships between overall acceptance and each item were analyzed (Figure 2B). Appearance, taste, and overall acceptance were evaluated as a preference, and hardness and chewiness were evaluated as intensity.

As expected, the control sample WN showed the highest overall acceptance score. In appearance and taste preference assessment, WN was superior to CNs, and these preference results were highly correlated with the overall acceptance. The sensory texture of the noodles could be evaluated through the measurement of hardness and chewiness (Nouri et al., 2015). All sensory properties were highly correlated with the overall acceptance (R^2>0.9). Chewiness intensities of CNs were lower than that of WN. Whereas hardness showed the opposite results. Asian consumers generally prefer smooth and elastic noodles, therefore hard noodles, such as al dente, may be evaluated negatively by Asian people (Fu & Malcolmson, 2010). In addition, this was because the panels received brittleness while testing CNs compared to WN and felt that the feeling was due to the CN's high hardness (Petitot et al., 2010). It seems that the residues by brittleness decreased the preference for noodles. Among CNs, the sensory properties of CN-T were close to those of WN in all the items.

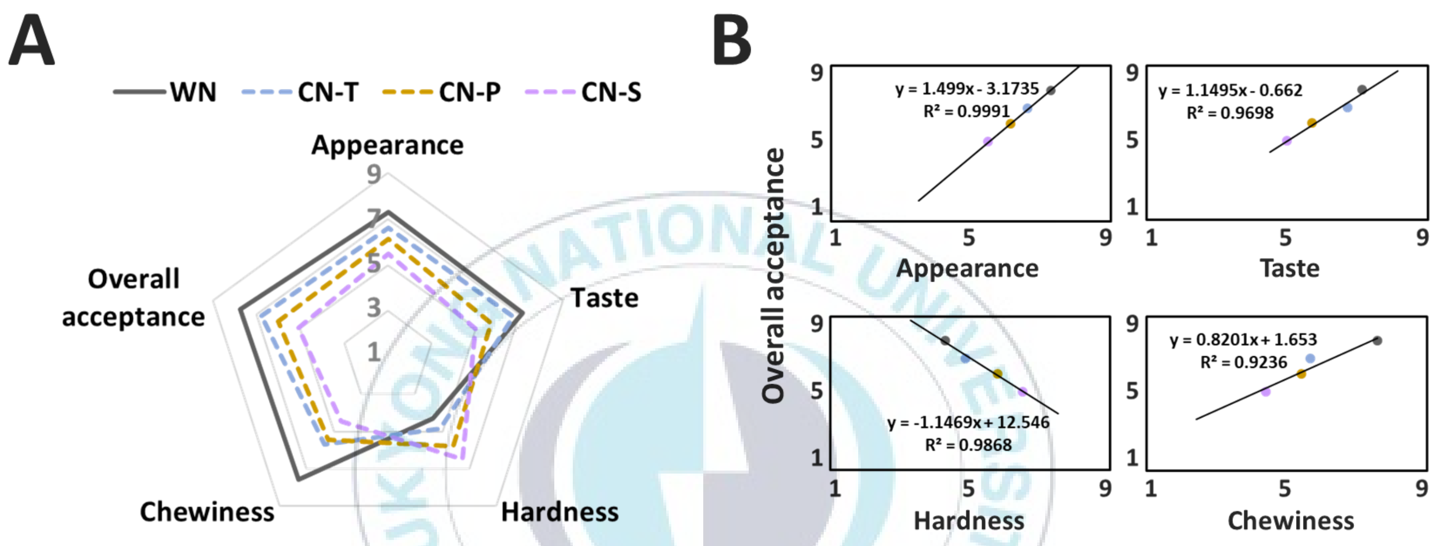

Figure 2. Sensory evaluation of cooked chicken breast meat noodles (CN) and wheat flour noodle (WN) (A) and the relations between overall acceptance and other sensory properties (B). Overall acceptance, appearance, and taste were assessed as preference, and hardness and chewiness were assessed as intensity. T, tapioca starch; P, potato starch; S, sweet potato starch.

2. Colors

Color and lightness representing visual appearances are key purchasing determinants of noodle products (Hatcher et al., 2009). Table 2 shows the CIE color values of the CNs and WN before and after cooking. Among the uncooked noodles, the CNs were observed to have lower L^* values (lightness) and higher a^* values (redness) than WN. These results originated from the myoglobin in the uncooked CBM (Mancini & Hunt, 2005; Liu et al., 2016). In the cooked noodles, the a^* values of the CNs were still higher than WN. The L^* value of WN was greatly reduced compared to uncooked WN, while the declines of L^* values of CNs were less. Lee et al. (2014) reported a great decrease in brightness for both WN and starch noodles after cooking compared to before cooking. In contrast, the reason for the small decrease in the lightness of CNs may be that the lightness of CBM was increased by heat and denaturation (Bak et al., 2019). The b^* values of uncooked CNs were lower than uncooked WN, but the b^* value of CN-T was the highest in cooked noodles. These changes in the b^* values were affected by starch type (Mertz & Wang, 2011). As in this study, Rachman et al. (2019) observed that there was little change in b^* values before and after cooking noodles with tapioca starch. Although there were significant differences in color parameters in uncooked noodles, the color values of CNs in cooked noodles were not much different compared to WN likewise the appearance of noodles (Figure 1).

Table 2. International commission on illumination (CIE) color values of chicken breast meat noodles (CN) and wheat flour noodle (WN) before and after cooking

Group	L^*		a^*		b^*	
	Uncooked	Cooked	Uncooked	Cooked	Uncooked	Cooked
WN	91.19 ± 0.49[a]	76.98 ± 0.35[b]	0.645 ± 0.54[c]	-3.184 ± 0.75[d]	23.47 ± 0.26[a]	15.57± 0.35[c]
CN-T	83.84 ± 0.40[b]	74.04 ± 0.11[c]	2.825 ± 0.35[ab]	-2.626 ± 0.35[cd]	19.75 ± 0.13[c]	19.19± 0.20[b]
CN-P	79.39 ± 0.29[d]	73.59 ± 0.33[d]	2.041 ± 0.69[b]	-2.369 ± 0.36[bc]	21.16 ± 0.20[b]	13.79 ± 0.29[e]
CN-S	79.27 ± 0.32[e]	72.97 ± 0.20[e]	1.054 ± 0.90[c]	-1.859 ± 0.20[b]	19.50 ± 0.22[c]	14.66 ± 0.04[d]

T, tapioca starch; P, potato starch; S, sweet potato starch. Data are shown as mean ± standard deviation (n=10). Different letters indicate significant differences (p<0.05) in Tukey's multiple comparisons test.

3. Texture properties

In order to investigate the difference between CNs and WN and the relation of sensory properties in more detail, the texture properties of noodles were analyzed. The texture of noodles, which is closely related to the consumer's acceptability, is influenced by ingredients, shapes, and processing methods (Barak et al., 2014; Nishinari et al., 2008; Park et al., 2017). It has been known that noodles with proper hardness and smooth surface conditions are preferred (Silva et al., 2013).

Hardness is the force required to compress the noodle between molar teeth and has a proportional effect on brittleness and chewiness (Petitot et al., 2010; Pons & Fiszman, 1996). The hardness values of CNs were higher than that of WN as in hardness of sensory property and were especially significant in texture property (p<0.001) (Figure 3A). Khare et al. (2015) reported that the hardness of wheat flour noodles with whole meat of chicken increased as the content of chicken meat increased, due to the mechanical resistance of the myofibrillar structure and the amount of connective tissues. Among CNs, CN-P showed the highest hardness value. This would be because potato starch gel was harder than the gel of other starches or wheat flour, so the mixture of potato starch affected the hardness of CN-P (Jung et al., 1991). The relation between the hardness of texture property and overall acceptance was insignificant (Figure 3B). Although this was different from the results of the relation between the hardness of sensory property and overall acceptance, it was similar to showing an inversely proportional trend.

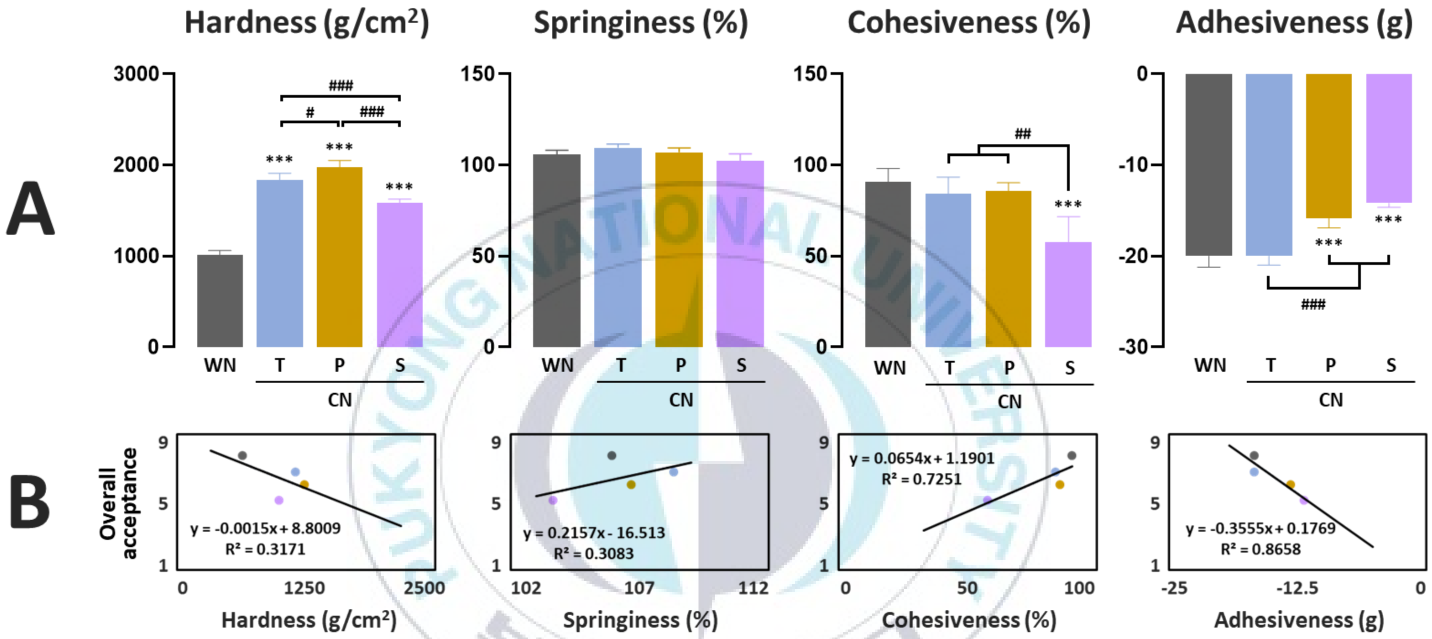

Figure 3. Texture profile analysis of cooked chicken breast meat noodles (CN) and wheat flour noodle (WN) (A) and the relations between overall acceptance and individual texture parameters (B). $^{***}p$<0.001, significant difference as compared to the WN (Tukey's test). $^{\#}p$<0.05, $^{\#\#}p$<0.05, $^{\#\#\#}p$<0.001, significant difference among CNs. T, tapioca starch; P, potato starch; S, sweet potato starch.

Gluten-free foods generally had less viscoelastic properties because of the lack of gluten protein (Lee et al., 2014). However, in this study, CNs were insignificantly different compared to WN (Figure 3A). This may be due to the interaction of starch with myofibrillar protein in CBM instead of the gluten structure contributed to the formation of springiness in CNs by increasing the gel strength (Jamilah et al., 2009).

The low cohesiveness value of the noodle means that it breaks well during cooking or ingestion and is closely related to lower consumer acceptability and processability (Tan et al., 2009). Therefore, cohesiveness can be considered an indicator that is the difficulty of breaking down the noodle (Shan et al., 2013). Cohesiveness values of CN-T and CN-P had no significant difference from WN, while CN-S was significantly different (p<0.001). Sweet potato starch had more branches per amylose molecule than potato and tapioca starch, requiring higher amounts of water for starch gelatinization (Li et al., 2022; Tan et al., 2009). It suggested that the same time of cooking noodles was insufficient to form the starch-protein network of CN-S, resulting in significantly lower cohesiveness values of CN-S. Therefore, adding water to the dough of CN-S or increasing the cooking time should be necessary. The relation between cohesiveness and overall acceptance was proportional (Figure 3B). The low cohesiveness of CN-S synergized with the high hardness of CN, leading to high brittleness (Petitot et al., 2010). The hardness of CN-S in sensory property was high due to high brittleness. These directly induced the worst overall acceptance in CN-S. As in the study of Tan et al. (2009), this could be suggested that cohesiveness is an important factor in determining sensory properties.

Adhesiveness is a surface property and a measure of food stickiness while eating (Brenner & Nishinari, 2014; Huang et al., 2007). Adhesiveness was in inverse relation to a smoothness which was the required characteristic of noodles after cooking (An et al., 2021). The adhesiveness of CN-T was insignificantly different from that of WN (Figure 3A), while CN-P and CN-S were significant (p<0.001). Compared to other starches, the amylose content of tapioca starch was low, resulting in reduced adhesiveness of noodles (An et al., 2021; Obadi & Xu. 2021). As reported by An et al. (2021), adhesiveness was the most related property to overall acceptance among mechanical texture items of noodles, and it was in an inverse proportion (Figure 3B).

4. Cooking properties

The changes in the weight and volume of noodles during cooking indicate the water uptake (Jamilah et al., 2009). The texture properties of noodles have been affected by the interaction of starch and protein caused by hydration (Nouviaire et al., 2008). Factors such as hydrophilicity and the gel-forming ability of starch and protein sources influence the WAC and VER of noodles (Rafiq et al., 2021). The WAC of CN-T and CN-S did not show significant differences compared to that of WN (p>0.05) (Figure 4A). The high water-holding capacity of myofibril protein in CBM made the WAC of CNs similar to that of WN (Huff-Lonergan & Lonergan, 2005; Pongpichaiudom & Songsermpong, 2018). In particular, CN-P showed a significant difference among CNs (p<0.05). This might be because potato starch had a large granule size than other starches, so

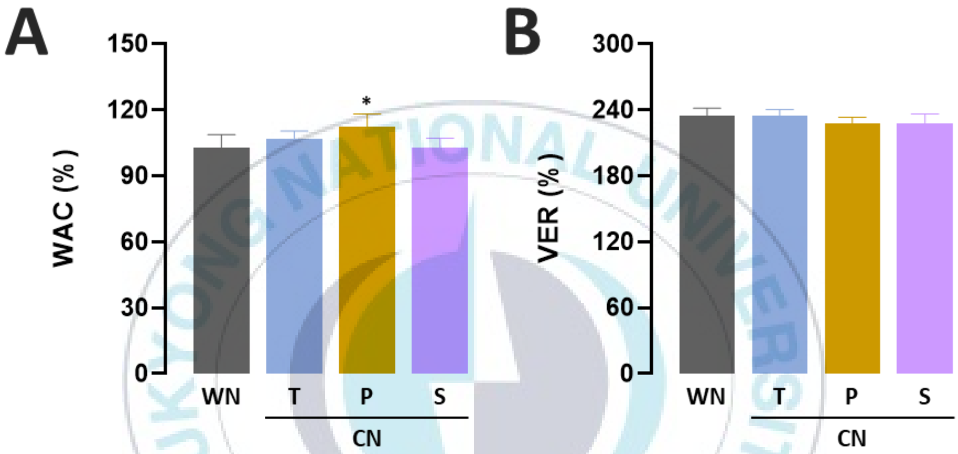

Figure 4. Water absorption capacity (WAC) (A) and volume expansion ratio (VER) (B) of cooked chicken breast meat noodles (CN) and wheat flour noodle (WN). $^{*}p<0.05$, significant difference as compared to the WN (Tukey's test). T, tapioca starch; P, potato starch; S, sweet potato starch.

gelatinization of CN-P among CNs occurred quickly (Obadi & Xu, 2021; Puncha-arnon et al., 2008).

The VERs of all samples were insignificantly different from each other (Figure 4B). According to Fan et al. (2017), in the fish protein/starch gel network, amylose from the starch granules permeated into the myofibrillar protein matrix as it gelatinized. Compared to other noodles, in spite of the WAC of CN-P being significantly high, the VER of CN-P was similar. It could be explained by the permeation of a relatively large amount of amylose in potato starch into myofibrillar protein than in other starches during the gelatinization process (Fan et al., 2017; Obadi & Xu, 2021). This was a reasonable basis for explaining the highest hardness value in CN-P.

5. Microstructure

The cross-sectional areas of the cooked noodles were observed in the outer and inner layers at three magnifications (×30, ×600, and ×1,500) by LV-SEM (Figure 5). The inner layers of microstructure in CNs were ungelatinized regions. The occurrence of ungelatinized regions implied that CNs required more cooking time (Liu et al., 2016; Sung, 2005). In this sense, if the CNs are sufficiently heated to remove ungelatinized regions, the WAC and VER of CNs will further increase. In the CNs, CN-T had the largest pore size and was structurally well bonded, leading to a decrease in adhesiveness (An et al., 2021). The tapioca starch had the lowest content of amylose compared to other starch (Obadi & Xu, 2021). The low content of amylose increased the smoothness of

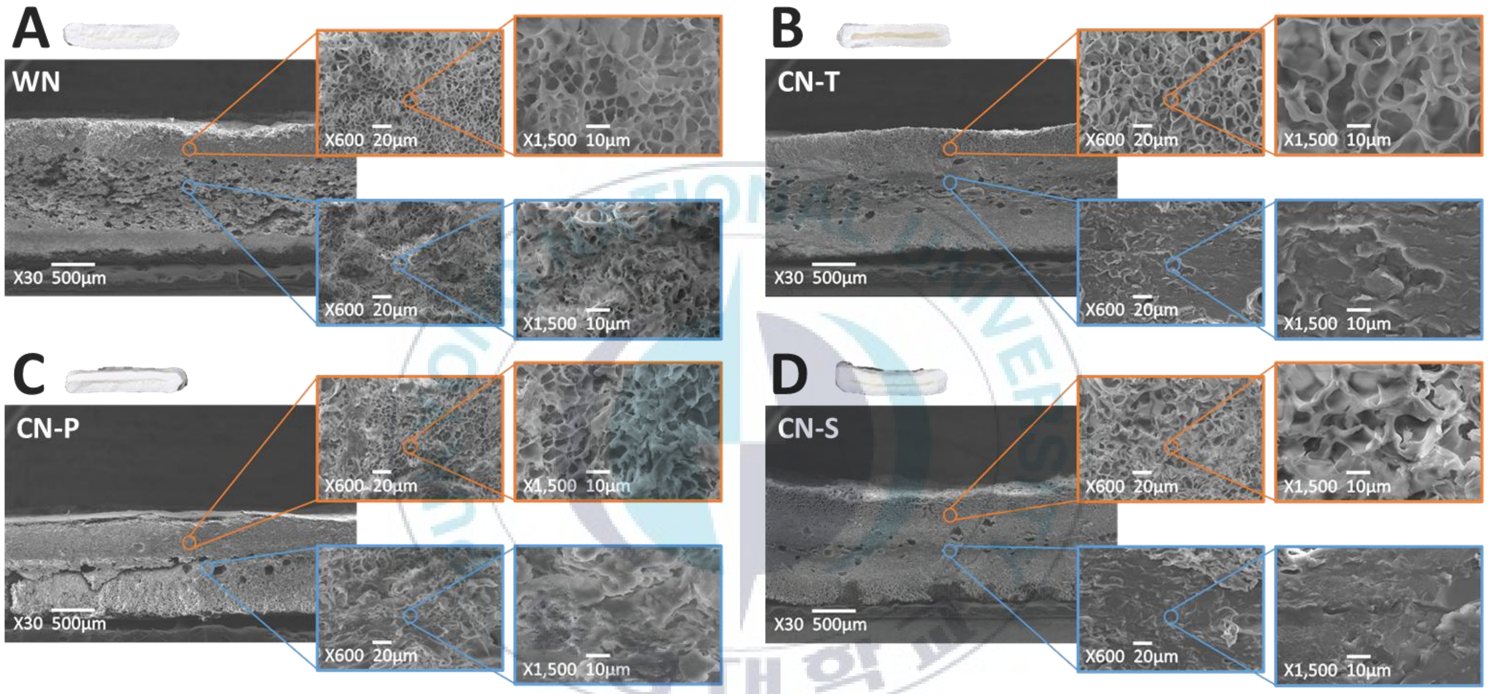

Figure 5. Scanning electron micrographs of cross-sectioned cooked noodles at ×30, ×600, and ×1,500. WN, wheat flour noodle (A); CN, chicken breast meat noodle; T, tapioca starch (B); P, potato starch (C); S, sweet potato starch (D).

noodles, resulting in low adhesiveness (An et al., 2021). The CN-P and CN-S, which had a relatively high amylose content than CN-T, interrupted interactions of myofibrillar protein and starch, resulting in poor fiber structure and increased adhesiveness (Fan et al., 2017; Chen et al., 2021).

6. Proximate compositions

To observe the change in the nutritional composition of noodles when adding the CBM, the proximate compositions of WN and CN-T were measured on a wet basis (Table 3). The CN-T was the best in overall acceptance among the CNs. The addition of CBM increased the protein content, resulting in a decrease in carbohydrates. The protein ratio of WN excluding moisture was similar to other papers (Ahmed et al., 2015; Liu et al., 2016). In CN-T, the protein content was about 2% higher than that of WN. To our best knowledge, in other papers, when meat is added to noodles, the maximum ratio of meat to semolina flour was 45:55 (Liu et al., 2016). However, in this study, CBM content was studied at a high level to determine the properties of gluten-free noodles added with CBM. Thus, it seems difficult to manufacture meat gluten-free noodles with a protein content of more than 6% unless a binder is added or the process is improved.

Table 3. Proximate compositions of cooked chicken breast meat noodle with tapioca starch (CN-T) and wheat flour noodle (WN)

	Proximate composition (g/100 g)	
	WN	CN-T
Moisture	72.18 ± 0.10	72.51 ± 0.11**
Carbohydrate	22.63 ± 0.23	20.45 ± 0.12***
Crude protein	4.07 ± 0.06	5.88 ± 0.07***
Crude lipid	1.06 ± 0.10	1.07 ± 0.11^{ns}
Ash	0.06 ± 0.00	0.09 ± 0.01^{ns}

Data are shown as mean ± standard deviation (n=3). ** p<0.05, *** p<0.001, significant difference as compared to WN (Holm-Sidak method). ns=no significance.

Conclusion

Although many studies have been conducted to develop gluten-free noodles, there were no reports of noodles with the addition of CBM without gluten. The aims of this study were the development and investigation of physicochemical and sensory characteristics of gluten-free noodles with the addition of CBM. For manufacturing gluten-free noodles, various starches and CBM were used in noodles instead of wheat flour. Among CNs, CN-T showed the most similar physicochemical and sensory characteristics to WN. There was no evaluation of various mixing ratios or processing methods to confirm the characteristics of the noodles. However, due to CN-T having similar physicochemical and sensory properties to WN, it was sufficient to confirm and contribute to expanding the possibility of gluten-free noodles. On the other hand, the structural bonding of CNs did not occur strongly before heating since the lack of gluten in noodles. This made it difficult to make noodles by spreading the dough thinly because the dough was crushed. Therefore, studies are needed to examine other additives or improve the processes to form structural bonds in the dough. Also, it is necessary to find the optimal mixing ratio and process conditions using statistics programs such as response surface methodology.

References

Ahmed, I., Qazi, I. M., & Jamal, S. (2015). Quality evaluation of noodles prepared from blending of broken rice and wheat flour. *Starch-Stärke*, 67(11-12), 905-912.

AOAC. (2003). Official methods of analysis of the association of official's analytical chemists, 17th edn. *Association of official analytical chemists (Arlington, Virginia)*.

Alireza Sadeghi, M., & Bhagya, S. (2008). Quality characterization of pasta enriched with mustard protein isolate. *Journal of Food Science*, 73(5), S229-S237.

An, D., Li, Q., Li, E., Obadi, M., Li, C., Li, H., . . . Li, N. (2021). Structural basis of wheat starch determines the adhesiveness of cooked noodles by affecting the fine structure of leached starch. *Food Chemistry*, 341, 128222.

Aronsson, C. A., Lee, H.-S., Liu, E., Uusitalo, U., Hummel, S., Yang, J., . . . Simell, O. (2015). Age at gluten introduction and risk of celiac disease. *Pediatrics*, 135(2), 239-245.

Bak, K., Bolumar, T., Karlsson, A., Lindahl, G., & Orlien, V. (2019). Effect of high pressure treatment on the color of fresh and processed meats: A review. *Critical Reviews in Food Science Nutrition*, 59(2), 228-252.

Barak, S., Mudgil, D., & Khatkar, B. (2014). Effect of compositional variation of gluten proteins and rheological characteristics of wheat flour on the textural quality of white salted noodles. *International journal of food properties*, 17(4), 731-740.

Brambila, G. S., Chatterjee, D., Bowker, B., & Zhuang, H. (2017). Descriptive texture analyses of cooked patties made of chicken breast with the woody breast condition. *Poultry Science*, 96(9), 3489-3494.

Brenner, T., & Nishinari, K. (2014). A note on instrumental measures of adhesiveness and their correlation with sensory perception. *Journal of Texture Studies*, 45(1), 74-79.

Chen, Q., Zhang, J., Zhang, Y., Meng, S., & Wang, Q. (2021). Rheological properties of pea protein isolate-amylose/amylopectin mixtures and the application in the high-moisture extruded meat substitutes. *Food Hydrocolloids*, 117, 106732.

Choi, Y.S., Hwang, K.E., Jeong, T.J., Kim, Y.B., Jeon, K.H., Kim, E.M., . . . Kim, C.J. (2016). Comparative study on the effects of boiling, steaming, grilling, microwaving and superheated steaming on quality characteristics of marinated chicken steak. *Korean Journal for Food Science of Animal Resources*, 36(1), 1.

Fan, M., Hu, T., Zhao, S., Xiong, S., Xie, J., & Huang, Q. (2017). Gel characteristics and microstructure of fish myofibrillar protein/cassava starch composites. *Food Chemistry*, 218, 221-230.

Fu, B. X., & Malcolmson, L. (2010). Sensory evaluation of noodles. *Asian noodles: Science, technology, processing*, 251-260.

Gao, Y., Janes, M. E., Chaiya, B., Brennan, M. A., Brennan, C. S., & Prinyawiwatkul, W. (2018). Gluten-free bakery and pasta products: prevalence and quality improvement. *International Journal of Food Science & Technology*, 53(1), 19-32.

Guo, X.N., Gao, F., & Zhu, K.X. (2020). Effect of fresh egg white addition on the quality characteristics and protein aggregation of oat noodles. *Food Chemistry*, 330, 127319.

Ha, J.H., Lee, J.H., Lee, J.J., Choi, Y.I., & Lee, H.J. (2019). Effects of whey protein injection as a curing solution on chicken breast meat. *Food science of animal resources*, 39(3), 494.

Hatcher, D., Dexter, J., & Fu, B. (2009). Refrigerated storage of yellow alkaline durum noodles: Impact on color and texture. *Cereal Chemistry*, 86(1), 106-112.

Huang, M., Kennedy, J., Li, B., Xu, X., & Xie, B. (2007). Characters of rice starch gel modified by gellan, carrageenan, and glucomannan: A texture profile analysis study. *Carbohydrate Polymers*, 69(3), 411-418.

Huff-Lonergan, E., & Lonergan, S. M. (2005). Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. *Meat science*, 71(1), 194-204.

Jamilah, B., Mohamed, A., Abbas, K., Rahman, R. A., Karim, R., & Hashim, D. (2009). Protein-starch interaction and their effect on thermal and rheological characteristics of a food system: A review. *Journal of Food, Agriculture and Environment*, 7(2), 169-174.

Jo, K., Lee, J., & Jung, S. (2018). Quality characteristics of low-salt chicken sausage supplemented with a winter mushroom powder. *Korean journal for food science of animal resources*, 38(4), 768.

Jung, S.H., Shin, G.J., & Choi, C.U. (1991). Comparison of physicochemical properties of corn, sweet potato, potato, wheat and mungbean starches. *Korean Journal of Food Science Technology*, 23(3), 272-275.

Khare, A. K., Biswas, A. K., Balasubramanium, S., Chatli, M. K., & Sahoo, J. (2015). Optimization of meat level and processing conditions for development of chicken meat noodles using response surface methodology. *Journal of food science technology*, 52(6), 3719-3729.

Kim, S.M., & Kim, E.J. (2009). Development of chicken breast noodles adding Rubus coreanum Miquel and Opuntia ficus-indica var. saboten. *Journal of the Korean Society of Food Science and nutrition*, 38(8), 1111-1117.

Kim, Y. (2019). Development of Chicken Breast Sausage with Addition of Mealworm (Tenebrio molitor Lavare) using Sensory evaluation. *International Journal of Internet, Broadcasting and Communication*, 11(3), 20-26.

Koh, H.Y., & Yu, I.J. (2015). Nutritional analysis of chicken parts. *Journal of the Korean Society of Food Science and nutrition*, 44(7), 1028-1034.

Kyarisiima, C., Naggujja, F., Magala, H., Kwizera, H., Kugonza, D., & Bonabana-Wabbi, J. (2011). Perceived tastes and preferences of chicken meat in Uganda. *Livestock research for rural Development*, 23(11), 1-7.

Landillon, V., Cassan, D., Morel, M.-H., & Cuq, B. (2008). Flowability, cohesive, and granulation properties of wheat powders. *Journal of Food Engineering*, 86(2), 178-193.

Lee, M.K., Shin, M.J., & Yoon, H. H. (2014). Effects of starches on the quality characteristics of raw and cooked noodles. *Culinary science hospitality research*, 20(4), 310-321.

Li, E., Cao, P., Cao, W., & Li, C. (2022). Relations between starch fine molecular structures with gelatinization property under different moisture content. *Carbohydrate Polymers*, 278, 118955.

Liu, T., Hamid, N., Kantono, K., Pereira, L., Farouk, M. M., & Knowles, S. O. (2016). Effects of meat addition on pasta structure, nutrition and in vitro digestibility. *Food Chemistry*, 213, 108-114.

Mancini, R., & Hunt, M. (2005). Current research in meat color. *Meat science*, 71(1), 100-121.

Mertz, A. W., & Wang, Y.J. (2011). Properties of gluten-free pasta prepared from rice and different starches. Discovery, The Student Journal of Dale Bumpers College of Agricultural, *Food Life Sciences*, 12(1), 67-73.

Nam, D.G., Jeong, B.G., & Chun, J. (2017). Physicochemical properties and oxidative stabilities of chicken breast jerky treated various sweetening agents. *Korean Journal of Food Preservation*, 24(1), 84-92.

Nishinari, K., Hayakawa, F., XIA, C. F., Huang, L., MEULLENET, J. F., & SIEFFERMANN, J. M. (2008). Comparative study of texture terms: English, French, Japanese and Chinese. *Journal of texture studies*, 39(5), 530-568.

Nouri, L., Nafchi, A. M., & Karim, A. (2015). Mechanical and sensory evaluation of noodles incorporated with betel leaf extract. *International journal of food engineering*, 11(2), 221-227.

Nouviaire, A., Lancien, R., & Maache-Rezzoug, Z. (2008). Influence of hydrothermal treatment on rheological and cooking characteristics of fresh egg pasta. *Journal of Cereal Science*, 47(2), 283-291.

Obadi, M., & Xu, B. (2021). Review on the physicochemical properties, modifications, and applications of starches and its common modified forms used in noodle products. *Food Hydrocolloids*, 112, 106286.

Oh, J. H., Kim, H. K., Yu, G. H., Jung, K. I., Kim, S. J., Jung, J. M., . . . Kong, C.-S. (2017). Quality characteristics and optimization of fish-meat noodle formulation added with olive flounder (Paralichthys olivaceus) using response surface methodology. *Journal of the Korean Society of Food Science Nutrition*, 46(11), 1373-1385.

Oh, N., Seib, P., & Chung, D. (1985). Noodles. III. Effects of processing variables on quality characteristics of dry noodles. *Cereal Chemistry*, 62(6), 437-440.

Oyeniran, A., Olorunsanya, A., Zahraddeen, D., & Olugbemi, T. (2021). Quality characteristics of wheat noodles fortified with spent Shika Brown hen meat powder. *Nigerian Journal of Animal Science*, 23(3), 271-277.

Park, B.H., Park, Y.K., Jo, K.H., Jeon, E.R., Koh, K.M., & Choi, Y.B. (2017). Quality characteristics of semi-dry noodles with different water contents. *Journal of the Korean Society of Food Culture,* 32(2), 135-143.

Park, C. S., & Baik, B. K. (2002). Flour characteristics related to optimum water absorption of noodle dough for making white salted noodles. *Cereal Chemistry*, 79(6), 867-873.

Petitot, M., Boyer, L., Minier, C., & Micard, V. (2010). Fortification of pasta with split pea and faba bean flours: Pasta processing and quality evaluation. *Food Research International*, 43(2), 634-641.

Pongpichaiudom, A., & Songsermpong, S. (2018). Evaluation of microstructure and quality characteristics of microwave-dried instant noodles enriched with chicken meat, egg yolk, and seaweed. *Journal of Food Measurement Characterization*, 12(1), 22-34.

Pons, M., & Fiszman, S. (1996). Instrumental texture profile analysis with particular reference to gelled systems. *Journal of texture studies*, 27(6), 597-624.

Puncha-arnon, S., Pathipanawat, W., Puttanlek, C., Rungsardthong, V., & Uttapap, D. (2008). Effects of relative granule size and gelatinization temperature on paste and gel properties of starch blends. *Food Research International*, 41(5), 552-

561.

Rachman, A., Brennan, M. A., Morton, J., & Brennan, C. S. (2019). Effect of cassava and banana flours blend on physico-chemical and glycemic characteristics of gluten-free pasta. *Journal of food processing preservation*, 43(9), e14084.

Rafiq, S. I., Muzaffar, K., Rafiq, S. M., Saxena, D., & Dar, B. (2021). Underutilized horse chestnut (Aesculus indica) flour and its utilization for the development of gluten-free pasta. *Italian Journal of Food Science*, 33(SP1), 137-149.

Sapone, A., Bai, J., Ciacci, C., Dolinsek, J., Green, P., Hadjivassiliou, M., . . . Fasano, A. (2012). Spectrum of gluten-related disorders: consensus on new nomenclature and classification. *BMC medicine*, 10(1), 1-12.

Shan, S., ZHU, K. X., Peng, W., & ZHOU, H. M. (2013). Physicochemical properties and salted noodle-making quality of purple sweet potato flour and wheat flour blends. *Journal of Food Processing Preservation*, 37(5), 709-716.

Shi, H., Zhang, X., Chen, X., Fang, R., Zou, Y., Wang, D., & Xu, W. (2020). How ultrasound combined with potassium alginate marination tenderizes old chicken breast meat: Possible mechanisms from tissue to protein. *Food Chemistry*, 328, 127144.

Silva, E., Birkenhake, M., Scholten, E., Sagis, L., & Van der Linden, E. (2013). Controlling rheology and structure of sweet potato starch noodles with high broccoli powder content by hydrocolloids. *Food Hydrocolloids*, 30(1), 42-52.

Sung WC. (2005). Microstructural studies of pasta and starch pasta. *Journal of Marine Science and Technology*, 13(2), 2.

Tan HZ, Li ZG, & Tan B. (2009). Starch noodles: History, classification, materials, processing, structure, nutrition, quality evaluating and improving. *Food Research International*, 42(5-6), 551-576.

Veraverbeke, W. S., & Delcour, J. A. (2002). Wheat protein composition and properties of wheat glutenin in relation to breadmaking functionality. *Critical reviews in food science and nutrition*, 42(3), 179-208.

Violalita, F., Syahrul, S., Yanti, H., & Fahmy, K. (2020). Characteristics of Gluten-Free

Wet Noodles Substituted with Soy Flour. *Paper presented at the IOP Conference Series: Earth and Environmental Science.*

Wieser, H. (2007). Chemistry of gluten proteins. *Food microbiology*, 24(2), 115-119.

Williams, S., & Damron, B. (1998). Sensory and objective characteristics of broiler meat from commercial broilers fed rendered whole-hen meal. *Poultry science*, 77(2), 329-333.

Xu, J., Zhang, Y., Wang, W., & Li, Y. (2020). Advanced properties of gluten-free cookies, cakes, and crackers: A review. *Trends in food science & technology*, 103, 200-213.