Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.106722

Comparative study on the edible quality and protein digestibility of diced chicken with mushroom from Prefabricated product and traditional cooked

Yuchao CHAO[1,2], Lingxia SUN[1,2*], Mengyuan NIU[1], Zhongmin HUANG[1,3,4], Miaoyun LI[1,2], Gaiming ZHAO[1,2], Zhili PAN[1,3,4]

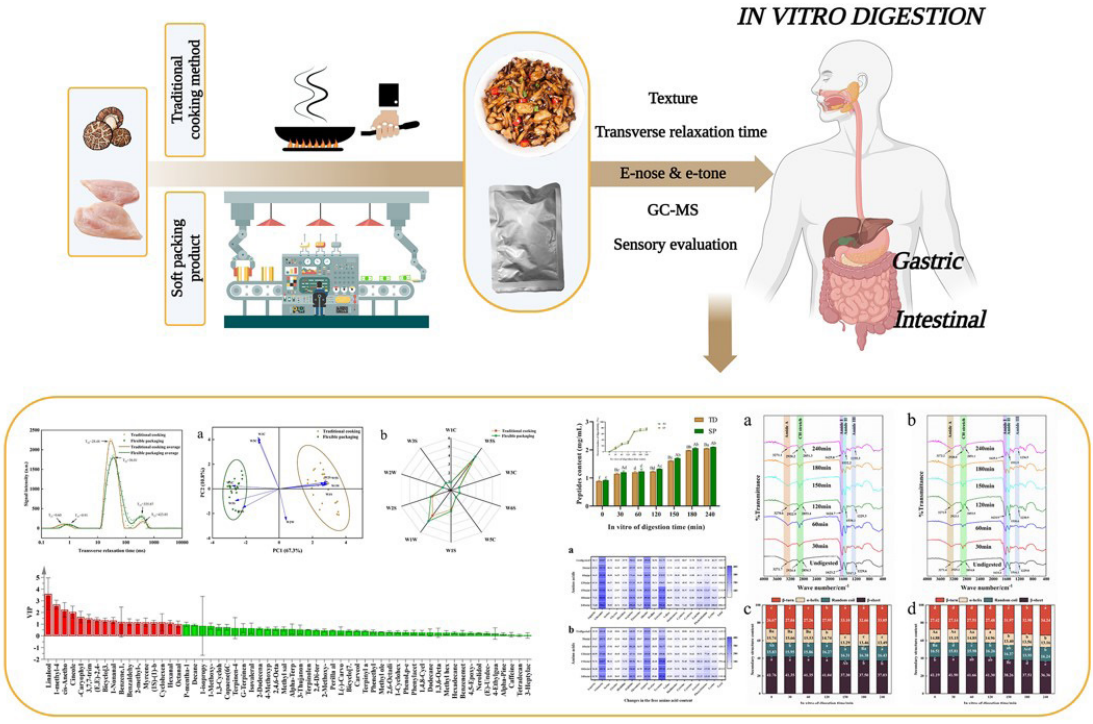
Abstract

The diced chicken with mushroom was taken as the research object to investigate the differences in quality and protein digestion characteristics between traditional (TD) cooked and prefabricated (ST) product. The results showed that compared to TD cooked, the acceptability and flavor of sensory evaluation of ST product decreased significantly, while the taste and chewiness improved remarkably. In addition, the bound and immobilized water were found transferred to free water indicated the water holding capacity decreased and meat softened. The analysis of gas chromatography-mass spectrometry (GC-MS) indicated that hexal, octanal and volatile substances from spices were the key substances causing flavor differences between the two methods and could be further distinguished by the electronic nose and tongue. The results of digestion in vitro showed that the protein digestibility, release rate of peptide and free amino-acid in the ST product were higher than that in the TD cooked. The contents of α-helix and β-sheet decreased with the increase of digestion time in the two methods, while the α-helix content of the ST product was lower during the first 60 min of intestinal digestion than that in TD cooked. These findings give a new insight into the associations of processing methods with meat quality.

Keywords: diced chicken with mushroom; traditional cooked; prefabricated product; texture; flavor; protein digestion.

Practical Application: The result presented in the current study may work as a basis for the production of prefabricated dish products that suit consumers' health needs and applications.

Graphical abstract



Received 21 Oct., 2022
Accepted 18 Dec., 2022
[1] *College of Food Science and Technology, Henan Agricultural University, Zhengzhou, China*
[2] *Key Laboratory of Meat Processing and Quality and Safety Control of Henan Province, Zhengzhou, China*
[3] *Key Laboratory of Bulk Grain Processing, Ministry of Agriculture, Zhengzhou, China*
[4] *National R&D Center For Frozen Rice&Wheat Products Processing Technology, Zhengzhou, China*
*Corresponding author: linger198003@163.com

1 Introduction

Diced chicken with mushroom is one of the traditional Chinese dishes with excellent color, aroma and taste. Traditional cooked was complex and not suitable for the fast-paced modern life. The foods of the prefabricated product have the characteristics of easy operation, convenient storage and rich variety. It has been the best choice for people to be the meal replacements, meals for travel and emergency reserves for a long time. It is also used in the fields of military supplies and disaster relief (Barba et al., 2017). Especially, during the new crown epidemic, the prefabricated product it better reflects the advantages of convenience, not restricted by the occasion of consumption, and gradually become the ideal choice for people in special times (Llana-Ruiz-Cabello et al., 2015; Majid et al., 2018; Meng et al., 2019).

To prolong the shelf life, the prefabricated product is usually sterilized at a high temperature, which is easy to cause problems such as poor taste and loss of flavor (Yu et al., 2017). Sreenath et al. (2010) found that the texture of sardines packed in aluminum cans deteriorated due to heat sterilization; Kong et al. (2008) found that heating significantly altered the quality of chicken meat, including color, shear, and shrinkage. However, some studies had shown that high temperature sterilization promoted the decomposition of protein in meat products and improve their nutritional value (Hall & Moraru, 2021). For the chicken dish with mushroom, there is no comparative study on the quality characteristic and protein digestion characteristic between traditional cooked and prefabricated product.

This study compared the differences in quality and protein digestibility characteristics of diced chicken with mushroom between the traditional cooked and prefabricated product, attempts to find the similarities and differences between the two methods in taste, flavor and nutrient digestion, and analyzes the reasons for the differences, which could provide a theoretical basis for its industrial and standardized production.

2 Materials and methods

2.1 Sample preparations

Chicken breast, salt, spices, mushroom and other materials were purchase from Shuang hui meat store, Zheng Zhou city, Henan province, China. Fascia and grease on the surface of the meat were cleaned, and the meat was cut into 1.5 cm × 1.5 cm × 1.5 cm cubes. Then, the flavorings were mixed based on meat weight: 2.2% oyster sauce, 5% egg, 0.2% white pepper, 1.67% edible corn starch, 2% cooking wine and 0.33% salt. These mixtures were pickled at 4 °C for 30 min, then in the 150 °C fried for 30 s. The mushroom was soaked in water for 4 h, then cut into cubes. The fried chicken and cut mushrooms were used in the next two types of products.

Traditional (TD) cooked

The soybean oil was added to the pot heated at 180 °C for 20 s using an induction cooker (RT2140, Midea, Zhengzhou, China). Then 15 g of chili, 15 g of hemp pepper, 10 g of Chinese pepper and 10 g of star anise were added and stir-fried until the sample was fragrant. After add 150 g Pixian broad bean sauce and let the red oil comes out. Add the fried chicken breast (1 000 g), mushroom and stir-fry for 5 minutes. Finally, add 670 mL of water, 60 g of chicken essence and 6.7 g of salt. The mixture was simmered at 110 °C for 4 min.

Prefabricated (ST) product

Pour the soybean oil into a pot heated at 180 degrees for 20 seconds on an induction cooker. The following flavorings were mixed based on the weight of the meat: 1.5% chili, 1.5% hemp pepper, 1.0% Chinese pepper and 1.0% star anise. The mixture was added to the pot for about 20 s. Then add 15% Pixian broad bean sauce and stir-fry for 15 s, add 67% water, 0.67% salt, and 0.6% chicken essence and stir-fry for 10 s. Strain the spices to make the sauce. Finally, each bag contains 85 g of fried chicken breast, 15 g of shiitake mushrooms, and 35 g of sauce. Then seal and high temperature sterilization. The sterilization formula was 15 min - 15 min - 10 min / 121 °C.

The raw materials and dosage of the above two processing methods are consistent to avoid affecting the results.

2.2 Quality index measurements

Texture profile analysis (TPA)

Texture analysis was carried out using a double compression test. A texture analyzer (TA.XT plus, Stable Micro System ltd. Godalming, UK) equipped with a cylindrical aluminum probe (P/50). The other testing conditions were as follows: pre-test speed, 2 mm/s; test speed, 1.5 mm/s; post-test speed, 1 mm/s; and the time interval between two compressions, 3 s (Gradinarska et al., 2022). For each sample, texture measurements were conducted by five times.

Transverse relaxation time (T_2) measurements

Water distribution was measured by low field nuclear magnetic resonance (LF-NMR) transverse relaxation with a Niumag Pulsed NMR analyzer (PO001, Niumag Corporation, Shanghai, China) and analyzed using the MultiExp Inv Analysis program (Version 4.08, Niumag Corporation, Shanghai, China). The measurements were performed according to the method of Niu et al. (2017) with some modifications. Samples of 2 g were placed in a glass tube with a diameter of 15 mm and put in the L-NMR apparatus. The spine-spin relaxation (T_2) was measured based on the CPMG sequence. The parameter settings were as follows: spectral width 200 kHz, the proton frequency 22 MHz, the repeat scan 16, and the measurement temperature 32 °C.

E-Nose & E-Tongue analysis

Taste analysis using the E-tongue (iTongue20, THINKSENSO, USA). First, 15 g sample was placed into a 250 mL triangle bottle and 150 mL ultrapure water was added This was then placed in a water bath at 50 °C for 30 min. The mixed solution was then centrifuged at 3 000 r/min (Rotational Speed) for 10 min to obtain the supernatant. After, the supernatant was filtered through qualitative filter paper to obtain the tested solution.

Sensors were washed for 90 s. and balanced for 30 min to ensure a stable baseline. The duration of each measurement was 30 s.

Odor analysis was performed using an E-nose (Win Muster Air Sense Analytics Inc., Schwerin, Germany). First, 10 g sample was placed into a 250 mL triangle bottle, sealed and heated in the water bath at 35 °C for 5 min. A probe was inserted into the sealed bottle to exude the flavor through a drainage membrane. The test conditions were as follows: sample test time was 80 s: cleaning time was 120 s; the internal flow rate was 300 mL/min; and the sample flow rate was 300 mL/min.

GC-MS Analysis

First, thawed and chopped the sample, then 2 g was placed in a 20 mL headspace bottle. Flavor extraction was then carried out by using solid phase microextraction (SPME) fiber (50/30 μm CAR/PDMS/DVB; Merck company, Kenilworth, NJ, USA). GC-MS analysis of the extracts was performed on a SCION SQ 456-GC (Bruker, Birrika, MA, USA) equipped with a DB-Wax column (30 m × 0.25 mm i.d., film thickness 0.25 μm). The GC temperature conditions were as follows: the furnace temperature was maintained at 40 °C for 3 min, then increased to 80 °C at the rate of 10 °C/min, heated to 150 °C at the rate of 2.5 °C/min, heated to 230 °C at the rate of 20 °C/min, and kept at 230 °C for 5 min. Volatile compounds were identified based on comparisons of their mass spectra with those in the NIST 17 database and by matching the RI values with those reported in the literature. The peak area normalization method was used for quantitative analyses and the relative contents of volatile substances were obtained.

Sensory evaluation

The sensory evaluation involved 18 students from the College of Food undergraduate and graduate students of Henan Agricultural University. The sensory attributes of the tested diced mushroom chicken samples were taste, aroma, color, tenderness, and overall acceptability with a total score of 100, and the weight of each index was 20%, 25%, 20%, 25%, and 10%, respectively.

2.3 In vitro digestion index measurement

In vitro digestion

In vitro pepsin-pancreatic enzyme in vitro digestion simulations were set up using an in vitro digestion simulator (GI 20, Nutriscan, USA) to perform the experiments. The experiments were performed according to Baugreet et al. (2019) with some modifications. Before digestion, diced chicken with mushroom sample (1 g) was mixed into 4mL PBS (10 mmol/L, pH 7.0) and homogenized (8 on/off cycles with a 10 000 rpm for 30 s at 4 °C) by a homogenizer (IKA, Germany). The sample solution after homogenization was adjusted to pH 2.0 by 1 M HCl solution, and pepsin was digested at 37 °C for 2 h by adding pepsin to the reaction system at a final concentration of 6 mg/mL. The gastric digesta was collected at 0, 30, 60, and 120 min, adjusting pH 7.0 to stop the simulated gastric digesta reaction. Then the reactant after pepsin digestion (pH 7.5) was used as substrate for trypsin digestion at 37 °C for 2 h by adding trypsin at a final concentration of 6 mg/mL to the reaction system. The trypsin digestion reaction was terminated by heating at 90 °C for 5 min, and intestine digesta was collected at 30, 60, and 120 min, respectively. The supernatant and precipitate were collected respectively for subsequent tests through refrigerated centrifugation (Beckman, USA) for 20 min at 4 °C, 10 000 r/min.

Determination of digestibility (DT)

The digestibility was calculated to evaluate the ratio of protein residues and total proteins after pepsin or pepsin/trypsin digestion. The protein contents before and after digestion were detected by the Kjeldahl method (Wang et al., 2021). The in vitro digestibility was calculated using the Equation 1 as follows:

$$DT(\%)=\frac{W_0-W_D}{W_0}\times 100\% \quad (1)$$

Where DT represents the digestibility of protein, W_0 represented the protein contents of the sample before the digestion and W_D represented the protein contents after the digestion.

Determination of peptide content

The peptide content of sample before and after in vitro digestion was determined according to the method of Wei et al. (2022). The digestion product (5 mL) was mixed with an equal volume of 10 trichloroacetic acids (West Asia Chemical Co, Ltd, Chengdu, China) solution and left for 30 min. Then the mixture was centrifuged at 4 °C, 4000 r/min for 15 min, and measure the absorbance value of the supernatant at 540 nm. The absorbance value was into the bovine serum standard curve ($y = 0.00\,128x + 0.02\,163$, $R^2 = 0.999$) to calculate the peptide content.

Fourier transform infrared spectroscopy (FTIR)

Fourier-transform infrared spectroscopy spectra of sample were scanned using a Bruker FTIR spectrometer (TENSOR-II, BRUKER, GER) as reported previously (Liu et al., 2022). The digestion supernatant was freeze-dried for spectroscopic analysis. Then the air was used as a blank for determination minus the background, the spectrum was scanned in the range of 400 – 4 000 cm^{-1}, resolution 4 cm^{-1}, and the repeat scan 32 times.

Free amino acid analysis

Profiles of amino acids were analyzed using HPLC (Alliance®, Waters 2695) with an Ultimate® Amino Acid column (250 mm × 4.6 mm, 5 μm, 40 °C) according to an analysis kit (Welch, Shanghai, China). The kit was able to analyze up to 17 amino acids. Samples were subjected to pre-column phenylisothiocyanate derivatization (Hu et al., 2022). The injection volume was 10 μL. Mobile phases were A (93% 0.1 M NaAc, pH 6.5 and 7% acetonitrile, v/v) and B (80% acetonitrile and 20% water, v/v) at 1 mL/min flow rate. The target compound was detected by a photodiode array detector (Waters 2996, Waters Corp., MA, USA) at 254 nm, identified, and quantified according to the retention time and calibration curve of the corresponding standard, respectively.

2.4 Statistical analysis

All data (except the texture) were made three times and expressed as mean ± standard error analyzed by using SPSS statistics (SPSS 20.0 Inc., USA), and one-way analysis of variance, Paired t-test, and Duncan's multiple range test was performed at a significance level of 0.05.

3 Results and discussion

3.1 Sensory, texture, and transverse relaxation properties analysis

In commercial sterilization at 121 °C, cell rupture due to excessive heat treatment tends to soften the texture of meat products, which is more prone to water loss and hardening during storage, a common phenomenon (Barbosa-Cánovas et al., 2014). The sensory organ evaluations of the two processing methods were shown in Figure 1a. Compared to the dishes made by the TD cooked which was highly accepted in overall sensory by their appetizing smell, and plentiful flavor with shiny and ruddy color. However, the taste of ST product had a higher score, owing to its meat quality being pulpier so that people could masticate easily, which may not be conducive to the long-term storage of packed dishes.

To better understand the rules in ST product with more tender, TPA and LF-NMR were used to measure the structural changes of food and the resulting changes in degrees of freedom of water molecules. Combined with Figure 1b, the hardness, cohesiveness, gumminess, chewiness ability and resilience of ST product were significantly lower than that of TD cooked ($p < 0.05$), and there was no obvious change in springiness ($p > 0.05$). This was due to the high temperature of 121 °C high-temperature sterilization, which led to cell rupture, protein degradation and gelation in chicken breast, thus resulting in the softness of chicken breast (Westphalen et al., 2006).

Three peaks appeared in the LF-NMR multi-exponential inversion spectrum, which was bound water (T_{21}, 1 - 10 ms), immobilized water (T_{22}, 10 - 100 ms), and free water (T_{23}, 100 – 1 000 ms), respectively. Peak-integrated area ratios S_{21}, $S_{22,}$ and S_{23} represented the relative content of hydrogen protons, S_{23} could also represent the microstructural damage degree of the diced chicken with mushroom (Cheng et al., 2018; Zhang et al., 2022). Combined Figure 1c and Figure 1d, the results showed that compared with TD cooked, the peak position of T_{21} and T_{22} moved to the right, the water mobility in the sample increased and the low degrees of freedom water migrated toward the high degrees of freedom, resulting in a decrease of water retention. The content of bound water (S_{21}) in the ST product and the TD cooked ($p > 0.05$) had no significant change, the content of immobilized water (S_{22}) was lower than the TD cooked ($p < 0.05$), and the content of free water (S_{23})

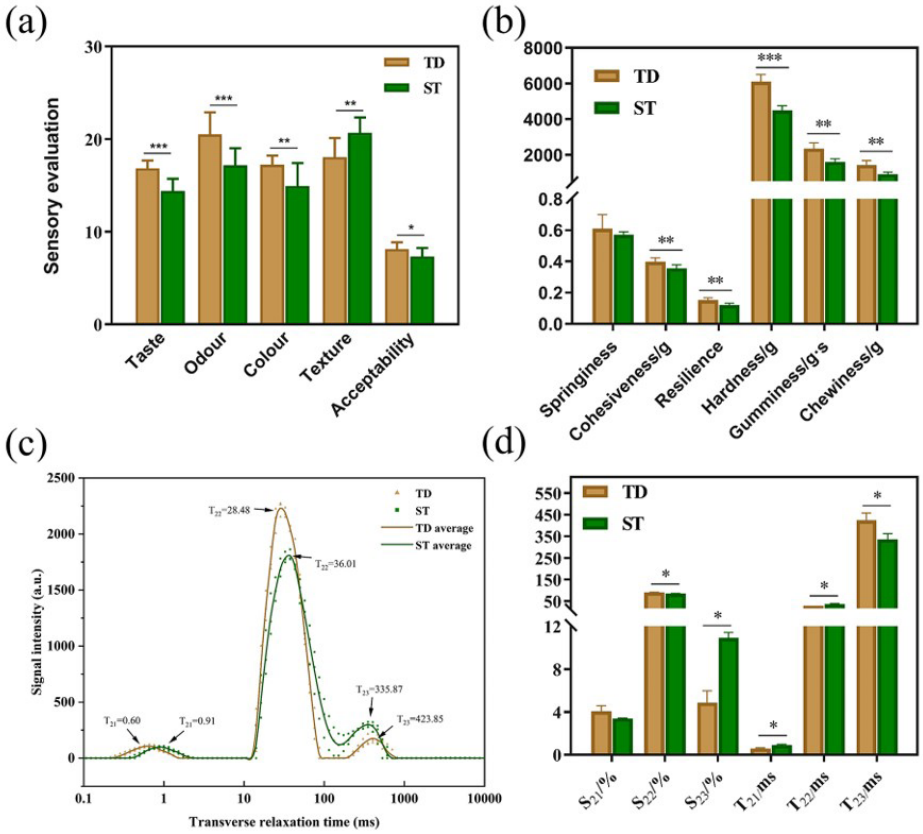


Figure 1. Sensory evaluation (a), texture profile (b), multiple exponent inversion spectra (c), and changes of lateral relaxation parameter (d) with two processes of the diced chicken with mushroom (The yellow bars and lines were traditionally cooked, the green bars and lines were prefabricated product).

was higher ($p < 0.05$). It could be that the chicken breast of the ST product under the high temperature sterilization condition was tender and rotten, breaking the hydrogen bond between the binding of water molecules and macromolecules, which led to aggravating the escape ability of water and structural destruction (Song et al., 2021).

3.2 Flavor profiles analysis

Electronic tongue and nose analysis

The flavor was an important index of dishes (Spence, 2020), using electronic tongue and nose to analyze the taste of samples. The odor analysis from electronic nose was shown in Figure 2a and 2b. 67.3% and 10.8% for PC1 and PC2, respectively, which could reflect most of the characteristic information of the samples. The TD cooked was distributed on the positive axis of PC1, while the ST product was on the negative axis of PC1, indicating that the processing method had an obvious effect on the odor and that the sensor could effectively differentiate the dishes from the two methods (Du et al., 2021). The response values of W5S (highly sensitive to nitrogen oxides) and W1W (sensitive mainly to sulfides, and pyrazine) from ST product were higher than that from TD cooked, perhaps high temperature sterilization was conducive to the release of these volatile substances.

The taste analysis from electronic tongue was shown in Figure 2c. The contributions of PC1 and PC2 were 64.0% and 14.2%, respectively, which reflected most of the characteristic information of the sample. The sample from TD cooked was on the negative axis of PC1 and the ST product was on the positive axis of PC1, which indicated that the processing method had an obvious effect on the taste. It could be that high temperature sterilization at 121 °C led to strong interactions between proteins and fats, which resulted in a change of taste (Li et al., 2022).

Volatile compounds analysis

The volatile compounds of the two methods were examined by GC-MS and the results were shown in Table 1. 55 and 53 volatile compounds were identified in the TD and ST methods, respectively, with the highest relative content of alcohols, and main linalool from the spices. Compared to the TD cooked, the relative content of aldehydes in the ST product was increased ($p < 0.05$), and its threshold value was lower, which had a great influence on the flavor, mainly endowing fatty and grassy flavor. The relative contents of ketones, hydrocarbons, and esters in the ST were significantly decreased than that in the TD ($p < 0.05$) (Wu et al., 2020).

In order to further compare the effects of the two processing methods on the characteristic volatile compounds in products, the PLS-DA model was established based on the peak area of volatile compounds, as shown in Figure 3. According to the PLS-DA variable importance for the projection (VIP), 17 volatiles with VIP > 1 were obtained from 58 volatiles, which could be used as important metabolic markers to distinguish the two processing modes (Figure 3b) (Ríos-Reina et al., 2019). Differentiation analysis and flavor substance analysis of the aroma ingredients of diced chicken with mushroom dishes greater than VIP > 1 were performed, and the results were shown in Table 2. Except for linalool, 16 volatile compounds were significantly different ($p < 0.05$), which may be the key compounds to distinguish the odor of the two cooking methods. These mainly come from the hydrocarbon in the spices. The different processing methods may make the volatile substance content unknown, which leads to a change in smell.

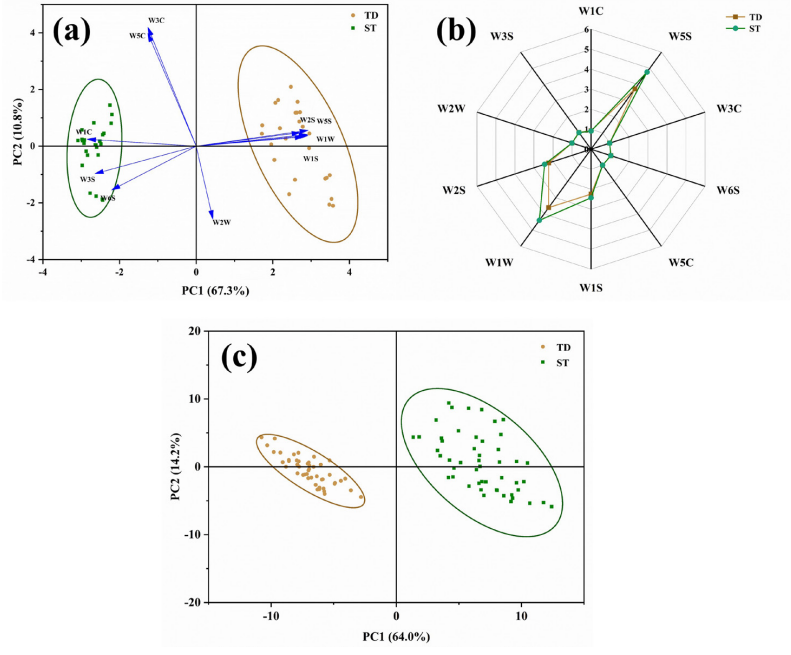


Figure 2. E-nose and E-tongue analysis. E-nose PCA plot (a), E-nose Radar graph (b), and E-tongue PCA plot (c) with two processes of the diced chicken with mushroom.

Table 1. The volatile composition of diced chicken with mushroom under the conditions of two processing methods.

Volatile	No	Volatile compounds	Content (%)	
			TD	ST
Aldehydes	1	Isovaleraldehyde	1.001 ± 0.042	1.105 ± 0.026
	2	Hexanal	0.280 ± 0.009[a]	0.586 ± 0.007[b]
	3	Benzaldehyde	0.406 ± 0.003[a]	0.743 ± 0.051[b]
	4	Octanal	0.107 ± 0.003[a]	0.353 ± 0.042[b]
	5	Phenylacetaldehyde	0.167 ± 0.001	0.144 ± 0.011
	6	1-Nonanal	0.404 ± 0.009[a]	0.821 ± 0.040[b]
	7	trans-2-Decenal	0.066 ± 0.002	0.066 ± 0.023
	8	1-Cyclohexene-1-carboxaldehyde,4-(1-methylethyl)-	0.056 ± 0.003[a]	0.080 ± 0.004[b]
	9	trans,trans-2,4-Decadien-1-al	0.843 ± 0.056[b]	0.377 ± 0.040[a]
	10	trans-2-Undecenal	0.049 ± 0.001[b]	0.036 ± 0.004[a]
	11	Tetradecanal	0.035 ± 0.000	0.037 ± 0.007
	12	2-Dodecenal, (E)-	0.096 ± 0.001	n.d.
Ketones	Total		3.511 ± 0.113[a]	4.346 ± 0.011[b]
	1	3-Thujanone(8CI)	0.564 ± 0.032[a]	0.636 ± 0.019[b]
	2	L(-)-Carvone	0.468 ± 0.008	0.522 ± 0.025
	3	1-methyl-4-	1.722 ± 0.008	n.d.
	4	Caffeine	0.042 ± 0.001	0.046 ± 0.007
	5	4-Methoxyphenylacetone	n.d.	0.088 ± 0.010
	Total		2.797 ± 0.040[b]	1.292 ± 0.046[a]
Hydrocarbon	1	alpha-Pinene	0.259 ± 0.013	0.259 ± 0.005
	2	p-mentha-1,5-diene	0.289 ± 0.010[a]	0.514 ± 0.017[b]
	3	Myrcene	1.576 ± 0.023[b]	1.248 ± 0.048[a]
	4	3-carene	0.635 ± 0.025[a]	1.175 ± 0.052[b]
	5	1,3-Cyclohexadiene,1-methyl-4-(1-methylethyl)-	0.682 ± 0.013[b]	0.552 ± 0.019[a]
	6	Cyclohexene,1-methyl-4-(1-meth	3.420 ± 0.107[b]	3.056 ± 0.165[a]
	7	1,3,6-Octatriene,3,7-dimethyl-	0.483 ± 0.032	0.465 ± 0.026
	8	g-Terpinene	0.838 ± 0.033	0.722 ± 0.047
	9	Copaene(6CI)	0.065 ± 0.004[a]	0.078 ± 0.003[b]
	10	l-Caryophyllene	1.386 ± 0.048[a]	2.021 ± 0.097[b]
	11	Humulene	0.096 ± 0.006[a]	0.117 ± 0.007[b]
	12	4,5-Epoxy-4,11,11-trimethyl-8-	0.030 ± 0.002[a]	0.043 ± 0.002[b]
	13	Terpinolene	0.064 ± 0.005	n.d.
	14	Estragole	0.730 ± 0.008[a]	0.900 ± 0.040[b]
	15	cis-Anethol	10.266 ± 0.392[b]	9.063 ± 0.163[a]
	16	Dodecane	0.144 ± 0.002	0.118 ± 0.022
	17	Hexadecane	0.071 ± 0.004	0.054 ± 0.004
	18	Decane	0.206 ± 0.010	n.d.
	19	(1S)-(1)-beta-Pinene	n.d.	0.322 ± 0.018
	20	2,4,6-Octatriene,2,6-dimethyl-	n.d.	0.088 ± 0.017
	21	(-)-ISOCARYOPHYLLENE	n.d.	0.045 ± 0.006
	Total		21.856 ± 0.611[b]	21.313 ± 0.544[a]
Alcohols	1	Cineole	6.111 ± 0.181[b]	5.096 ± 0.144[a]
	2	4-Thujanol(6CI,7CI,8CI)	1.896 ± 0.077[b]	1.470 ± 0.018[a]
	3	alpha-Terpineol	2.207 ± 0.159	2.230 ± 0.041
	4	Linalool	55.772 ± 1.292	58.884 ± 0.202
	5	Phenethyl alcohol	0.134 ± 0.007[a]	0.166 ± 0.003[b]
	6	Terpinen-4-ol	2.635 ± 0.139	2.529 ± 0.042
	7	2,6-Octadien-1-ol,3,7-dimethyl-, (2Z)-	0.109 ± 0.001[a]	0.135 ± 0.006[b]
	8	Carveol	0.058 ± 0.000[a]	0.100 ± 0.001[b]
	9	p-Cymen-7-ol(7CI,8CI)	0.173 ± 0.007	0.189 ± 0.008
	10	Nerolidol	0.080 ± 0.001[b]	0.064 ± 0.001[a]
	11	Perilla alcohol	0.050 ± 0.001	n.d.
	Total		69.222 ± 0.832	70.864 ± 0.066
Phenols	1	4-Ethylphenol	0.173 ± 0.001[a]	0.196 ± 0.006[b]
	2	4-Ethyl-2-methoxyphenol	0.210 ± 0.009	0.189 ± 0.045
	3	2-Methoxy-4-vinylphenol	0.035 ± 0.001[a]	0.087 ± 0.008[b]
	4	2,4-Di-tert-butylphenol	n.d.	0.055 ± 0.001
	Total		0.418 ± 0.011	0.528 ± 0.058

n.d.: not detected. TD: Traditional cooked; ST: prefabricated product. Data are means ± standard deviations. Values in the same line with different letters are significantly different ($p < 0.05$).

Table 1. Continued...

Volatile	No	Volatile compounds	Content (%)	
			TD	ST
Esters	1	Methyl salicylate	0.201 ± 0.002[b]	0.118 ± 0.019[a]
	2	Terpinyl acetate	0.231 ± 0.003[b]	0.189 ± 0.004[a]
	3	Methyl hexadecanoate	0.078 ± 0.003	0.059 ± 0.010
	4	2-methyl-, 3,7-dimethyl-2,6-octadienyl ester, (E)-Propanoic acid	0.331 ± 0.006	n.d.
	5	Methyl oleate	0.026 ± 0.001	n.d.
	Total		0.865 ± 0.002[b]	0.365 ± 0.027[a]
Other	1	Benzene,1,3-bis(1,1-dimethylethyl)-	1.533 ± 0.042[b]	1.214 ± 0.027[a]
	2	1-isopropyl-2-methylbenzene	0.415 ± 0.002	0.419 ± 0.014
	Total		1.953 ± 0.053[b]	1.630 ± 0.026[a]

n.d.: not detected. TD: Traditional cooked; ST: prefabricated product. Data are means ± standard deviations. Values in the same line with different letters are significantly different ($p < 0.05$).

Table 2. The VIP value and difference analysis of diced chicken with mushroom in two processing methods.

No.	Compounds	VIP value	Relative Percentage Content (%)		P-value	Aroma Characteristics
			TD	ST		
1	Linalool	3.581	55.772 ± 1.292	58.884 ± 0.202	0.057	Fruity
2	P-menth-1-en-3-one	2.667	1.722 ± 0.008	n.d.	0.000**	Camphor
3	Cis-Anethol	2.223	10.266 ± 0.392	9.063 ± 0.163	0.026*	Aniseed, licorice
4	Cineole	2.031	6.111 ± 0.181	5.096 ± 0.144	0.001**	Herbal
5	l-Caryophyllene	1.606	1.386 ± 0.048	2.021 ± 0.097	0.004**	Wood
6	3-carene	1.489	0.635 ± 0.025	1.175 ± 0.052	0.002**	Rosin
7	(E,E)-2,4-Decadien-1-al	1.384	0.843 ± 0.056	0.377 ± 0.040	0.001**	Fat
8	Sabin	1.321	1.896 ± 0.077	1.470 ± 0.018	0.013*	—
9	1-Nonanal	1.307	0.404 ± 0.009	0.821 ± 0.040	0.002**	Fat
10	Benzene,1,3-bis(1,1-dimethylethyl)-	1.180	1.533 ± 0.042	1.214 ± 0.027	0.003**	—
11	Benzaldehyde	1.170	0.406 ± 0.003	0.743 ± 0.051	0.007**	Almond
12	Cis-3,7-dimethyl-2,6-octadien-	1.168	0.331 ± 0.006	n.d.	0.000**	Rose
13	Myrcene	1.154	1.576 ± 0.023	1.248 ± 0.048	0.015*	Pepper
14	(1S)-(1)-beta-Pinene	1.152	n.d.	0.322 ± 0.018	0.001**	Pine
15	Cyclohexene,1-methyl-4-(1-meth	1.147	3.420 ± 0.107	3.056 ± 0.165	0.009**	Lemon
16	Hexanal	1.124	0.280 ± 0.009	0.586 ± 0.007	0.000**	Grass
17	Octanal	1.001	0.107 ± 0.003	0.353 ± 0.042	0.008**	Fruity

n.d.: not detected. TD: Traditional cooked; ST: prefabricated product. P´Data are means ± standard deviations. Mean with superscripts of different small letters in the same row were tested by paired t-test. *$p < 0.05$. **$p < 0.001$.

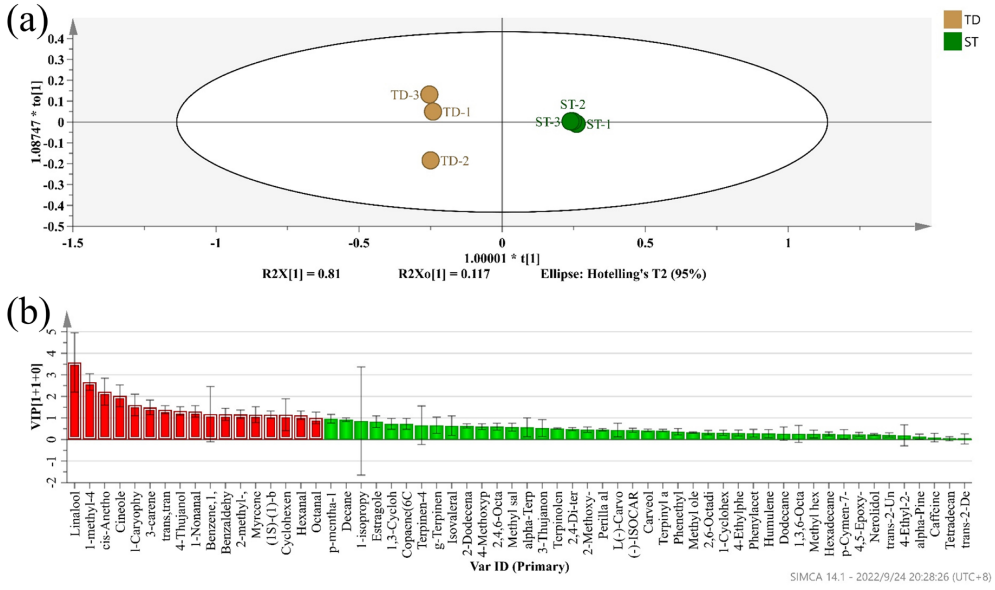


Figure 3. Partial least-squares discriminant (PLS-DA) analysis of GC-MS results for diced chicken with mushroom by two processing methods. Principal component analysis scores plot of volatile compounds (a) and Variable importance in the projection (VIP) values of key volatile compounds (b).

3.3 In vitro digested analysis

Protein digestibility and peptide content analysis

Protein digestibility rate and peptide content were important indicators of measuring the nutritional value of protein (Xie et al., 2022b). As shown in Table 3, in vitro digestibility rate and peptide content in both processing methods increased significantly with the increase of digestion time ($p < 0.05$). The protein digestibility rate in ST product was significantly higher than that in TD cooked ($p < 0.05$) during gastrointestinal digestion. There was no significant difference in peptide content between the two methods in the gastric digestion phase ($p > 0.05$). However, peptide content in ST was significantly higher than that in TD during the intestinal digestion phase ($p < 0.05$), which was due to the high temperature sterilization treatment was more likely to break the protein structure so that more hydrolysis sites were exposed and digestive enzymes were fully integrated with them (Luo et al., 2018).

Free amino acid analysis

As shown in Table 4 and Figure 4, the content of free amino acids in the two methods increased during digestion. The content of free amino acids (FAA) in TD cooked and ST product increased by 16.99% (from 1 325.74 to 1 550.73 mg/kg) and 20.69% (from 1 150.51 to 1 388.99 mg/kg) after pepsin digestion for 2 h, respectively. After further incubation for 2 h by pancreatin, the content of FAA increased by 79.83% (to 2 384.22 mg/kg) and 86.098% (to 2 140.96 mg/kg) compared to the undigested, there were significant differences. It was because pepsin was highly specific for the cleavage of peptide bonds and initially hydrolyzes proteins into large molecular weight peptides. However, after the addition of trypsin, the FAA increased in a stepwise manner, especially up to 83.88% in the ST product, which was because trypsin was an enzyme mixture that could be utilized by trypsin but could not be further hydrolyzed by amino acids or peptides acting on pepsin (Wu et al., 2023).

In the process of digestion, the FAA of ST product was lower than that of TD cooked method, while the release amount of FAA was higher than that of TD method ($p < 0.05$). It could be that the low structural integrity and increased free water content of chicken breast under the condition of high temperature sterilization, led to the loss of FAA. Besides the unfolding of protein structure was easy to form smaller peptide chain fragments, and it was easier to break down into smaller peptides and amino acids under the action of digestive enzymes, which may be another reason for the faster digestibility of proteins.

Fourier transform infrared spectroscopy (FTIR) analysis

Fourier transform infrared spectroscopy (FTIR) determination could reflect protein molecular interactions and protein structure changes (Muadiad & Sirivongpaisal, 2022). The amide I region (1 600 – 1 700 cm^{-1}), including α-helix (1 650 – 1 660 cm^{-1}), β-sheet (1 600 – 1 640 cm^{-1}), β-turn (1 660 – 1 700 cm^{-1}), and random coil (1 640 – 1 650 cm^{-1}) were used to analyze the secondary structure of proteins (Gao et al., 2019; Xie et al., 2022a). The protein secondary structure of the two processing methods was shown in Figure 5a and Figure 5b. For both processing methods, the contents of α-helix and β-sheet decreased with digestion time ($p < 0.05$), while the contents of β-turn and random coil were on the contrary ($p < 0.05$). The content of α-helix in ST product was significantly lower than that in the TD cooked within 60 min ($p < 0.05$), which was good for protein digestion (Jiang et al., 2022). Zielbauer et al. (2016) found that different methods caused

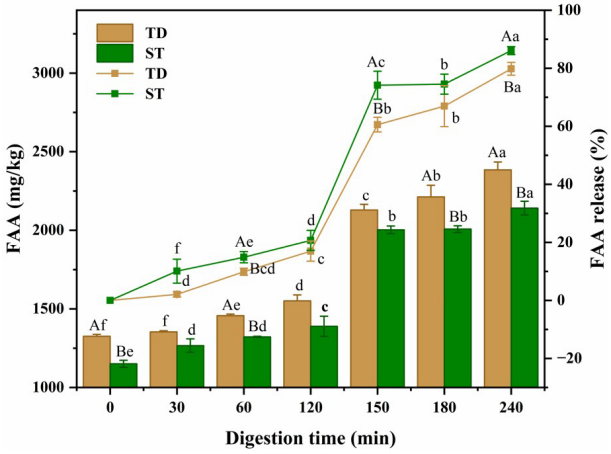


Figure 4. The variation of free amino acid content and release rate during in vitro digestion of two processing methods of diced chicken with mushroom (The bar shows the total FAA content and the line shows the total FAA release rate during digestion).

Table 3. The protein digestibility and peptide content of two processing methods of diced chicken with shiitake mushroom during in vitro digestion.

Digestion time (min)	Determination of digestibility (%)		Peptide content (mg/mL)	
	TD	ST	TD	ST
0 min	n.d.	n.d.	0.89 ± 0.02^{f}	0.92 ± 0.02^{e}
30min	10.03 ± 0.49^{fB}	14.91 ± 0.36^{fA}	1.15 ± 0.03^{eB}	1.20 ± 0.05^{dA}
60min	23.91 ± 0.36^{eB}	27.62 ± 0.59^{eA}	1.20 ± 0.04^{d}	1.23 ± 0.09^{d}
120min	28.38 ± 0.34^{dB}	34.25 ± 0.58^{dA}	1.23 ± 0.02^{dB}	1.32 ± 0.01^{cA}
150min	66.82 ± 0.25^{cB}	67.95 ± 0.29^{cA}	1.61 ± 0.02^{cB}	1.70 ± 0.02^{bA}
180min	70.30 ± 0.15^{bB}	75.69 ± 0.56^{bA}	1.98 ± 0.01^{bB}	2.06 ± 0.02^{aA}
240min	73.20 ± 0.27^{aB}	78.45 ± 0.06^{aA}	2.05 ± 0.02^{aB}	2.10 ± 0.01^{aA}

The values are expressed as mean ± standard deviation. The mean with superscripts of different capital letters in the same rows is significantly different from Paired t-test ($p < 0.05$). The mean with superscripts of different small letters in the same columns is significantly different from the Duncan test ($p < 0.05$).

Table 4. The variation of free amino acid content during in vitro digestion of two processing methods of diced chicken with mushroom.

Amino acids	FAA(mg amino acid/kg)													
	TD							ST						
	Undigested	30min	60min	120min	150min	180min	240min	Undigested	30min	60min	120min	150min	180min	240min
Aspartic	55.56 ± 3.09^{Bf}	63.25 ± 2.20^{Bef}	57.12 ± 5.10^{Bde}	64.76 ± 2.27^{cd}	69.89 ± 3.55^{Bbc}	76.70 ± 4.10^{Ba}	75.86 ± 3.68^{Bab}	34.86 ± 5.21^{Ae}	39.34 ± 1.47^{Ade}	41.68 ± 0.83^{Ad}	58.13 ± 5.47^{ab}	51.46 ± 0.31^{Ac}	56.85 ± 0.51^{Ab}	62.74 ± 0.49^{Aa}
Glutamic	273.09 ± 12.90^{d}	333.43 ± 5.33^{Bc}	356.14 ± 1.41^{Bbc}	363.51 ± 28.45^{Bb}	379.93 ± 22.27^{ab}	400.11 ± 5.52^{Ba}	403.53 ± 9.26^{Ba}	233.23 ± 6.24^{d}	252.12 ± 4.96^{Acd}	256.46 ± 22.56^{Acd}	264.49 ± 24.98^{Ac}	344.49 ± 8.22^{a}	302.91 ± 17.83^{Ab}	292.06 ± 5.73^{Ab}
Serine	41.20 ± 4.65^{Bde}	41.53 ± 3.64^{de}	39.37 ± 1.77^{Be}	45.55 ± 2.99^{Bd}	57.64 ± 1.86^{c}	64.26 ± 1.62^{b}	70.16 ± 3.37^{a}	31.94 ± 5.51^{Ac}	30.56 ± 2.81^{c}	29.08 ± 2.98^{Ac}	30.50 ± 1.03^{Ac}	58.03 ± 4.70^{a}	45.99 ± 5.84^{b}	47.20 ± 6.71^{b}
Glycine	17.34 ± 2.36^{Bc}	17.42 ± 1.68^{c}	17.58 ± 2.68^{Bc}	20.54 ± 0.86^{bc}	23.53 ± 1.34^{ab}	23.60 ± 0.93^{ab}	26.25 ± 2.84^{Ba}	11.12 ± 1.06^{Ab}	13.02 ± 1.40^{b}	9.97 ± 1.21^{Ab}	17.31 ± 2.71^{a}	16.68 ± 3.65^{a}	18.88 ± 1.51^{a}	20.34 ± 1.26^{Aa}
Histidine	39.21 ± 2.28^{bc}	33.39 ± 2.78^{c}	37.79 ± 6.71^{bc}	42.52 ± 6.30^{b}	64.49 ± 0.73^{a}	64.85 ± 2.42^{a}	65.43 ± 3.22^{Ba}	41.50 ± 6.44^{c}	40.61 ± 0.70^{c}	47.43 ± 7.67^{c}	45.26 ± 6.09^{c}	71.92 ± 5.26^{b}	68.97 ± 3.13^{b}	81.06 ± 1.93^{Aa}
Arginine	182.21 ± 4.85^{e}	192.96 ± 8.35^{de}	173.13 ± 22.95^{de}	203.91 ± 16.55^{cd}	225.62 ± 10.63^{c}	262.43 ± 10.46^{b}	287.56 ± 10.82^{a}	166.11 ± 10.12^{c}	177.85 ± 28.26^{c}	188.82 ± 24.73^{bc}	169.62 ± 8.01^{c}	211.99 ± 4.82^{b}	256.67 ± 1.04^{a}	258.93 ± 18.07^{a}
Threonine	40.97 ± 2.63^{c}	38.11 ± 5.97^{c}	43.62 ± 2.65^{c}	47.30 ± 5.79^{c}	61.19 ± 6.10^{b}	64.73 ± 8.79^{b}	77.10 ± 2.91^{Ba}	38.45 ± 4.97^{bc}	32.72 ± 8.93^{c}	37.54 ± 5.26^{bc}	32.17 ± 4.11^{c}	50.64 ± 5.98^{a}	45.14 ± 2.32^{ab}	50.46 ± 9.81^{Aa}
Alanine	261.87 ± 6.27^{b}	215.63 ± 15.99^{c}	253.66 ± 25.62^{b}	252.33 ± 14.55^{b}	303.67 ± 22.45^{a}	306.77 ± 12.44^{a}	326.61 ± 6.90^{Ba}	224.80 ± 27.08^{c}	223.45 ± 7.46^{c}	217.46 ± 33.86^{c}	244.25 ± 7.94^{bc}	288.14 ± 20.75^{a}	282.35 ± 25.61^{ab}	269.55 ± 15.38^{Aab}
Proline	35.90 ± 2.79^{c}	36.00 ± 3.71^{c}	38.88 ± 0.74^{c}	39.95 ± 6.31^{c}	53.54 ± 5.97^{b}	57.41 ± 8.75^{ab}	63.50 ± 3.36^{a}	35.88 ± 3.93^{bc}	28.95 ± 5.35^{b}	31.45 ± 7.37^{b}	31.92 ± 8.16^{b}	46.14 ± 7.81^{ab}	48.79 ± 2.23^{a}	50.81 ± 4.43^{a}
Tyrosine	146.46 ± 17.76^{b}	154.98 ± 14.32^{b}	172.25 ± 3.19^{Ab}	150.11 ± 3.07^{Ab}	340.79 ± 13.31^{a}	341.62 ± 19.10^{a}	360.03 ± 19.56^{Aa}	138.78 ± 4.44^{d}	195.35 ± 18.29^{c}	217.66 ± 6.85^{Bc}	193.89 ± 11.07^{Bc}	367.40 ± 20.45^{b}	368.93 ± 23.64^{b}	403.52 ± 7.52^{Ba}
Valine	22.62 ± 1.51^{b}	17.19 ± 2.81^{c}	21.93 ± 0.81^{bc}	24.58 ± 2.93^{b}	46.40 ± 3.78^{a}	46.91 ± 3.69^{a}	50.20 ± 2.69^{a}	17.52 ± 3.49^{bc}	16.57 ± 4.77^{c}	18.37 ± 1.67^{bc}	23.55 ± 4.96^{b}	46.17 ± 1.84^{a}	46.80 ± 3.24^{a}	46.78 ± 4.16^{a}
Methionine	42.47 ± 7.72^{b}	39.01 ± 15.40^{b}	48.84 ± 5.85^{b}	54.76 ± 9.09^{b}	81.40 ± 3.62^{a}	72.18 ± 3.48^{a}	75.05 ± 11.44^{a}	35.79 ± 8.44^{c}	43.09 ± 4.33^{bc}	35.70 ± 11.01^{c}	46.55 ± 7.98^{bc}	55.69 ± 3.61^{ab}	55.18 ± 7.68^{ab}	67.27 ± 11.87^{a}
Cysteine	19.48 ± 1.90^{d}	15.00 ± 2.34^{d}	19.58 ± 3.23^{d}	29.70 ± 3.37^{c}	57.10 ± 1.10^{b}	55.68 ± 2.93^{Ab}	69.35 ± 4.15^{a}	13.38 ± 4.71^{e}	19.96 ± 2.73^{d}	22.68 ± 2.19^{d}	28.36 ± 4.09^{c}	53.65 ± 2.08^{b}	57.32 ± 2.40^{Bb}	70.05 ± 0.71^{a}
Isoleucine	21.52 ± 3.74^{d}	34.61 ± 3.04^{c}	33.36 ± 2.99^{c}	35.15 ± 10.42^{c}	61.92 ± 5.43^{b}	67.80 ± 10.49^{ab}	75.16 ± 5.68^{a}	22.86 ± 8.55^{c}	28.51 ± 7.05^{bc}	31.11 ± 4.29^{bc}	34.85 ± 6.41^{b}	71.75 ± 3.70^{a}	64.88 ± 4.11^{a}	67.28 ± 6.60^{a}
Leucine	51.25 ± 9.04^{Bb}	45.04 ± 7.52^{b}	47.40 ± 15.15^{b}	57.46 ± 4.05^{b}	105.73 ± 13.21^{a}	103.16 ± 11.33^{a}	122.84 ± 12.49^{a}	40.74 ± 5.30^{Ad}	40.78 ± 7.07^{d}	51.71 ± 9.60^{cd}	57.41 ± 4.65^{c}	100.81 ± 5.45^{b}	90.72 ± 7.04^{b}	118.95 ± 8.15^{a}
Phenylalanine	29.76 ± 11.24^{d}	39.04 ± 1.53^{d}	54.84 ± 12.01^{c}	75.98 ± 8.26^{b}	121.44 ± 2.01^{Ba}	119.67 ± 12.42^{a}	129.28 ± 8.09^{a}	28.52 ± 4.52^{d}	44.78 ± 7.51^{d}	44.98 ± 10.56^{d}	69.90 ± 13.51^{c}	105.40 ± 4.39^{Ab}	119.66 ± 14.49^{ab}	135.38 ± 1.98^{a}
Lysine	44.83 ± 7.25^{a}	36.91 ± 5.26^{a}	41.12 ± 8.89^{a}	42.62 ± 2.84^{a}	74.50 ± 2.93^{c}	84.95 ± 2.72^{b}	106.32 ± 7.61^{a}	35.02 ± 10.04^{d}	38.66 ± 6.02^{d}	39.38 ± 5.78^{d}	40.84 ± 6.89^{d}	62.85 ± 5.89^{c}	77.46 ± 10.81^{b}	98.57 ± 10.10^{a}
Total	1325.74 ± 11.89^{Bf}	1353.49 ± 7.18^{f}	1456.61 ± 10.33^{Be}	1550.73 ± 38.34^{d}	2128.78 ± 36.18^{c}	2212.83 ± 73.47^{Bb}	2384.22 ± 50.42^{Ba}	1150.51 ± 22.52^{Ae}	1266.31 ± 43.41^{d}	1321.49 ± 4.03^{Ad}	1388.99 ± 64.55^{c}	2003.21 ± 23.88^{b}	2007.50 ± 21.49^{Ab}	2140.96 ± 43.50^{Aa}

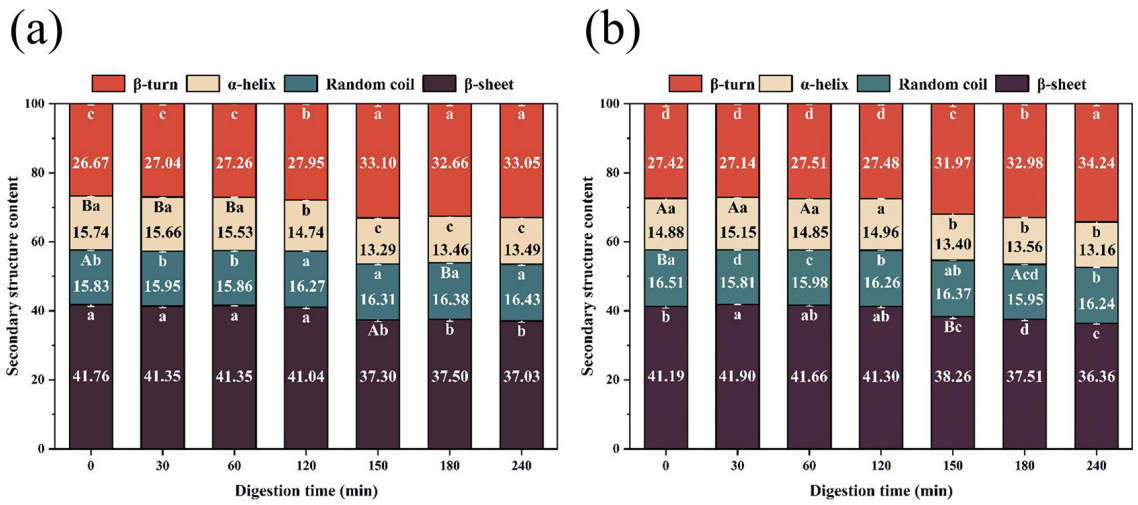


Figure 5. Protein structure analysis. The FAA content of traditional cooked (a), and prefabricated product (b) of diced chicken with mushroom during in vitro digestion.

changes in protein secondary structure, which led to differences in the sensitivity of protein to digestive enzymes. Therefore, the content of α-helix and β-sheet in the protein secondary structure caused the change in digestibility rate and made a difference in protein nutritional value (Ramos et al., 2013).

4 Conclusions

There were obvious differences in the edible quality and protein digestion characteristics of the diced chicken with mushroom made by the two processing methods. Compared to the TD cooked method, the overall sensory organ evaluation and flavor evaluation score of diced chicken with mushroom made by the ST product decreased significantly. However, the taste and chewiness were significantly improved. Besides, the bound water and immobilized water in the chicken were moved towards free water, and the quality of the meat became tender. The e-nose and e-tongue have shown that the diced chicken with mushroom flavor had apparent changes. GC-MS combined with VIP value showed that the relative contents of key flavor compounds including hydrocarbons, ketones and aldehydes were significantly different in diced chicken with mushroom, mainly due to the different terpenes in spices, which caused the difference in flavor. During the digestion process, the protein digestibility rate, peptide content and free amino acid release content in the ST product were significantly higher than that of the TD cooked method. The α-helix and β-sheet content of chicken protein decreased with increasing digestion time, and the α-helix content of the ST product was significantly lower than that of the TD cooked method within 60 min before intestinal digestion, which was more conducive to protein digestion. In conclusion, the diced chicken with mushroom made by the ST product provided better taste and protein digestion characteristics, while the flavor quality would decrease during high temperature sterilization. Therefore, flavor maintenance during the processing of the Prefabricated product dishes will be an important issue to be studied.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Funding

This research was funded by the National Key R&D Program of China (2018YFD0400502).

Author contributions

Yuchao Chao: Methodology, Writing – original draft preparation, Data treatment, Figure; Lingxia Sun: Methodology, Writing – review, editing and Funding acquisition; Mengyuan Niu: Data treatment, Part of the experiment; Zhongmin Huang: Project administration, Funding acquisition; Gaiming Zhao: Writing – review and editing; Miaoyun Li: Project administration, Writing – review; Zhili Pan: Investigation, Validation.

References

Barba, F. J., Koubaa, M., do Prado-Silva, L., Orlien, V., & Sant'Ana, A. S. (2017). Mild processing applied to the inactivation of the main foodborne bacterial pathogens: a review. *Trends in Food Science & Technology*, 66, 20-35. http://dx.doi.org/10.1016/j.tifs.2017.05.011.

Barbosa-Cánovas, G. V., Medina-Meza, I., Candoğan, K., & Bermúdez-Aguirre, D. (2014). Advanced retorting, microwave assisted thermal sterilization (MATS), and pressure assisted thermal sterilization (PATS) to process meat products. *Meat Science*, 98(3), 420-434. http://dx.doi.org/10.1016/j.meatsci.2014.06.027. PMid:25060584.

Baugreet, S., Gomez, C., Auty, M. A. E., Kerry, J. P., Hamill, R. M., & Brodkorb, A. (2019). In vitro digestion of protein-enriched restructured beef steaks with pea protein isolate, rice protein and lentil flour following sous vide processing. *Innovative Food Science & Emerging Technologies*, 54, 152-161. http://dx.doi.org/10.1016/j.ifset.2019.04.005.

Cheng, S., Zhang, T., Yao, L., Wang, X., Song, Y., Wang, H., Wang, H., & Tan, M. (2018). Use of low-field-NMR and MRI to characterize water mobility and distribution in pacific oyster (Crassostrea gigas) during drying process. *Drying Technology*, 36(5), 630-636. http://dx.doi.org/10.1080/07373937.2017.1359839.

Du, H., Chen, Q., Liu, Q., Wang, Y., & Kong, B. (2021). Evaluation of flavor characteristics of bacon smoked with different woodchips by HS-SPME-GC-MS combined with an electronic tongue and electronic nose. *Meat Science*, 182, 108626. http://dx.doi.org/10.1016/j.meatsci.2021.108626. PMid:34284220.

Gao, H., Ma, L., Li, T., Sun, D., Hou, J., Li, A., & Jiang, Z. (2019). Impact of ultrasonic power on the structure and emulsifying properties of whey protein isolate under various pH conditions. *Process Biochemistry*, 81, 113-122. http://dx.doi.org/10.1016/j.procbio.2019.03.012.

Gradinarska, D. N., Valkova-Yorgova, K. I., & Danov, K. R. (2022). Effect of red wine in dry fermented sausages produced with a starter culture for improving their quality and safety. *Food Science and Technology (Campinas)*, 42, e47722. http://dx.doi.org/10.1590/fst.47722.

Hall, A. E., & Moraru, C. I. (2021). Effect of high pressure processing and heat treatment on in vitro digestibility and trypsin inhibitor activity in lentil and faba bean protein concentrates. *LWT*, 152, 112342. http://dx.doi.org/10.1016/j.lwt.2021.112342.

Hu, K., Zhao, H., Edwards, N., Peyer, L., Tao, Y., & Arneborg, N. (2022). The effects of cell-cell contact between Pichia kluyveri and Saccharomyces cerevisiae on amino acids and volatiles in mixed culture alcoholic fermentations. *Food Microbiology*, 103, 103960. http://dx.doi.org/10.1016/j.fm.2021.103960. PMid:35082077.

Jiang, S., Xue, D., Zhang, Z., Shan, K., Ke, W., Zhang, M., Zhao, D., Nian, Y., Xu, X., Zhou, G., & Li, C. (2022). Effect of Sous-vide cooking on the quality and digestion characteristics of braised pork. *Food Chemistry*, 375, 131683. http://dx.doi.org/10.1016/j.foodchem.2021.131683. PMid:34865922.

Kong, F., Tang, J., Lin, M., & Rasco, B. (2008). Thermal effects on chicken and salmon muscles: tenderness, cook loss, area shrinkage, collagen solubility and microstructure. *Lebensmittel-Wissenschaft + Technologie*, 41(7), 1210-1222. http://dx.doi.org/10.1016/j.lwt.2007.07.020.

Li, K., Zhang, Z., Ye, H., Ren, W., Huang, L., & Chen, H. (2022). Processing optimization and quality assessment for the innovative product of canned soybean paste oyster. *Food Science and Technology (Campinas)*, 42, e93622. http://dx.doi.org/10.1590/fst.93622.

Liu, C., Huang, J., Hu, Y., & Wu, X. (2022). Functional properties, structural characteristics and biological activities of deer blood hydrolysates obtained by using different protease. *Food Science and Technology (Campinas)*, 42, e84722. http://dx.doi.org/10.1590/fst.84722.

Llana-Ruiz-Cabello, M., Pichardo, S., Baños, A., Núñez, C., Bermúdez, J. M., Guillamón, E., Aucejo, S., & Cameán, A. M. (2015). Characterisation and evaluation of PLA films containing an extract of Allium spp. to be used in the packaging of ready-to-eat salads under controlled atmospheres. *Lebensmittel-Wissenschaft + Technologie*, 64(2), 1354-1361. http://dx.doi.org/10.1016/j.lwt.2015.07.057.

Luo, J., Taylor, C., Nebl, T., Ng, K., & Bennett, L. E. (2018). Effects of macro-nutrient, micro-nutrient composition and cooking conditions on in vitro digestibility of meat and aquatic dietary proteins. *Food Chemistry*, 254, 292-301. http://dx.doi.org/10.1016/j.foodchem.2018.01.164. PMid:29548456.

Majid, I., Ahmad Nayik, G., Mohammad Dar, S., & Nanda, V. (2018). Novel food packaging technologies: Innovations and future prospective. *Journal of the Saudi Society of Agricultural Sciences*, 17(4), 454-462. http://dx.doi.org/10.1016/j.jssas.2016.11.003.

Meng, Q., Zhang, S., Yan, S., Zhang, Z., Wang, L., Zhang, Y., & Guan, H. (2019). Establishment of comprehensive quality evaluation model of fresh instant rice. *Food & nutrition research*, 63(0). PMid:31384243.

Muadiad, K., & Sirivongpaisal, P. (2022). Effect of frozen storage and hydrocolloids on structural and rheological properties of frozen roti dough supplemented with rice bran. *Food Science and Technology (Campinas)*, 42, e44620. http://dx.doi.org/10.1590/fst.44620.

Niu, H., Li, Y., Han, J., Liu, Q., & Kong, B. (2017). Gelation and rheological properties of myofibrillar proteins influenced by the addition of soybean protein isolates subjected to an acidic pH treatment combined with a mild heating. *Food Hydrocolloids*, 70, 269-276. http://dx.doi.org/10.1016/j.foodhyd.2017.04.001.

Ramos, B., Miller, F. A., Brandão, T. R. S., Teixeira, P., & Silva, C. L. M. (2013). Fresh fruits and vegetables: an overview on applied methodologies to improve its quality and safety. *Innovative Food Science & Emerging Technologies*, 20, 1-15. http://dx.doi.org/10.1016/j.ifset.2013.07.002.

Ríos-Reina, R., Segura-Borrego, M. P., García-González, D. L., Morales, M. L., & Callejón, R. M. (2019). A comparative study of the volatile profile of wine vinegars with protected designation of origin by headspace stir bar sorptive extraction. *Food Research International*, 123, 298-310. http://dx.doi.org/10.1016/j.foodres.2019.04.071. PMid:31284980.

Song, Y., Huang, F., Li, X., Han, D., Zhao, L., Liang, H., Rui, M., Wang, J., & Zhang, C. (2021). Water status evolution of pork blocks at different cooking procedures: a two-dimensional LF-NMR T1-T2 relaxation study. *Food Research International*, 148, 110614. http://dx.doi.org/10.1016/j.foodres.2021.110614. PMid:34507758.

Spence, C. (2020). Multisensory flavour perception: blending, mixing, fusion, and pairing within and between the senses. *Foods*, 9(4), 407. http://dx.doi.org/10.3390/foods9040407. PMid:32244690.

Sreenath, P. G., Abhilash, S., Ravishankar, C. N., Anandan, R., & Srinivasa Gopal, T. K. (2010). Heat penetration characteristics and quality changes of indian mackerel (rastrelliger kanagurta) canned in brine at different retort temperatures. *Journal of Food Process Engineering*, 32(6), 893-915. http://dx.doi.org/10.1111/j.1745-4530.2008.00252.x.

Wang, W., Li, Y., Zhou, X., Li, C., & Liu, Y. (2021). Changes in the extent and products of In vitro protein digestion during the ripening periods of Chinese dry-cured hams. *Meat Science*, 171, 108290. http://dx.doi.org/10.1016/j.meatsci.2020.108290. PMid:32949821.

Wei, G., Wang, D., Wang, T., Yang, C., Shi, Y., & Huang, A. (2022). Insights into in vitro digestion properties and peptide profiling of Chinese rubing PDO cheese prepared using different acidification technology. *Food Research International*, 158, 111564. http://dx.doi.org/10.1016/j.foodres.2022.111564. PMid:35840253.

Westphalen, A. D., Briggs, J. L., & Lonergan, S. M. (2006). Influence of muscle type on rheological properties of porcine myofibrillar protein during heat-induced gelation. *Meat Science*, 72(4), 697-703. http://dx.doi.org/10.1016/j.meatsci.2005.09.021. PMid:22061882.

Wu, W., Zhou, Y., Wang, G., Zhu, R., Ge, C., & Liao, G. (2020). Changes in the physicochemical properties and volatile flavor compounds of dry-cured Chinese Laowo ham during processing. *Journal of Food Processing and Preservation*, 44(8). http://dx.doi.org/10.1111/jfpp.14593.

Wu, X., Tan, M., Zhu, Y., Duan, H., Ramaswamy, H. S., Bai, W., & Wang, C. (2023). The influence of high pressure processing and germination on anti-nutrients contents, in vitro amino acid release and mineral digestibility of soybeans. *Journal of Food Composition and Analysis*, 115, 104953. http://dx.doi.org/10.1016/j.jfca.2022.104953.

Xie, D. D., Lei, Y. A., & Sun, Y. Q. (2022a). Effects of heating method and refrigerating time on nutritional quality and digestive characteristics of refrigerated Chinese steamed bread. *Food Science and Technology (Campinas)*, 42, e10122. http://dx.doi.org/10.1590/fst.10122.

Xie, Y., Cai, L., Zhao, D., Liu, H., Xu, X., Zhou, G., & Li, C. (2022b). Real meat and plant-based meat analogues have different in vitro protein digestibility properties. *Food Chemistry*, 387, 132917. http://dx.doi.org/10.1016/j.foodchem.2022.132917. PMid:35413556.

Yu, L., Turner, M. S., Fitzgerald, M., Stokes, J. R., & Witt, T. (2017). Review of the effects of different processing technologies on cooked and convenience rice quality. *Trends in Food Science & Technology*, 59, 124-138. http://dx.doi.org/10.1016/j.tifs.2016.11.009.

Zhang, L., Kong, L. M., Xv, D. Y., & Jiao, Y. Q. (2022). Effects of different soaking time and heating methods on the tenderness of mutton. *Food Science and Technology (Campinas)*, 42, e16121. http://dx.doi.org/10.1590/fst.16121.

Zielbauer, B. I., Franz, J., Viezens, B., & Vilgis, T. A. (2016). Physical aspects of meat cooking: time dependent thermal protein denaturation and water loss. *Food Biophysics*, 11(1), 34-42. http://dx.doi.org/10.1007/s11483-015-9410-7.