Physical properties and volatile compounds of beef flavors produced by direct extrusion

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Abstract. Beef flavors were formed by mixing amino acid, sugar, and wheat flour via the efficient and continuous direct extrusion process. The effect of the extrusion temperature of zone 1, at 80, 100 and 120°C, on the color, solubility, and sensory properties of the beef flavors obtained was investigated. Acceptability of extruded beef flavors, both in powder and liquid forms, was tested compared to the control, which was a commercial beef flavor prepared by the traditional method (boiling and reflux). Volatile compounds of the extruded product and the control were determined by GC-MS, with the solid-phase microextraction method (SPME). The bulk density of the extruded products was significantly higher than the control, but they all showed the same percentage of solubility. Methanethiol, the key component contributing to stewed beef and ground beef, as well as 2-furancarboxaldehyde, 3-(methylthiol)-propanal, 2-[(methylthio) methyl]furan, was detected in beef flavors both from extrusion and the control. Extrusion at higher temperatures, 100 and 120°C, indicated a more brownish color and obtained higher sensory scores in terms of odor, taste, and overall acceptance than samples extruded at 80°C and the control. Thus, there is a potential to use extrusion to replace traditional methods of production of beef flavors.

1. Introduction

Flavoring products such as seasoning powder and soup powder are popular and are used in food products because they can enhance odor and taste. The market for seasoning powder in Thailand was approximately 40,000 million Thai baht in 2016 [1] and is expected to increase by around 5% in the years 2018-2020 because of increases in food varieties for a convenient lifestyle.

There are different ethnic groups in Thailand, based on religion and culture, which leads to many choices of foods. Pork is prohibited for Muslims, who have halal food, while some Thai Buddhists do not eat beef, and vegetarians avoid eating meat altogether. Thus, it is interesting to create new food products to meet consumer demand in accordance with major religions and related to the food market.
Beef flavor is added to improve the flavor of vegetarian foods or to replace the loss of odor or taste during food processing. Beef flavors can be derived from non-beef/meat, and reaction flavors are made from the Maillard reaction occurring between amino acid and reducing sugar [2]. The reaction flavors will then be mixed with a carrier such as maltodextrin, and finally spray dried. However, this traditional method of producing beef flavor powder is a time-consuming and non-continuous process with high costs. The beef flavor powders should have a brown color, a clear beef aroma, and good solubility when they are added to food or food products. The traditional method for beef flavor production is via a nonenzymatic or Maillard reaction. The substrates of reducing sugar and the mixture of sulfur containing amino acid are allowed to react at high temperature for several hours [3-4]. Various intermediates and products from the Maillard reaction, such as furan derivatives, melanoidin, and compounds contributing to beef or meat flavors, are generated.

Extrusion is considered as an alternative process to produce seasoning flavor. It is gaining more and more popularity because it combines multiple processes such as cooking, mixing, and compressing in an extruder [5]. It is a highly efficient and continuous processing method with low effluent [6]. Extrusion can be run at high temperatures and for short time periods. Many studies on the development of foods produced by extrusion have been reported, such as spaghetti-like products from rice flour, snacks from various by-products, etc [7-8]. Darrington and Baek [9-10] investigated the formation of beef flavors by a twin screw extruder to produce beef flavors from amino acid and reducing sugar, while extrusion can be used for the formation of meat extender [11]. Consequently, the objective of this research was to study the formation of beef flavors by direct extrusion. Some physical properties, sensory indicators, as well as volatile compounds of the extruded samples were evaluated by GC-MS analysis and compared to the control, which was a commercial product produced by the traditional method.

2. Materials and Methods

2.1 Material

Beef flavors prepared by the reaction method with amino acid, sugar and wheat flour were obtained from Mighty International Co., Ltd. and used as the control. The reaction was done in a reactor for 1 h and vacuum-dried for 6 h before grinding into powder. The raw materials for the extrusion were also supplied by Mighty International Co., Ltd.

2.2 Preparation of beef flavors by direct extrusion

Amino acid, sugar, and wheat flour at the same ratio with the control were mixed and extruded via a single screw extruder (Barbender-1920, Germany) with barrel bore (D) 19.1 mm, barrel length (L) 20D, and screw compression ratio 4:1. The extruder was maintained at a screw speed of 60 rpm. The temperature of zone 1 was studied at 80°C, 100°C and 120°C, while the temperature of zone 2 was fixed at 50°C. The extruded sample was dried at 80°C in an oven for 3 h, then cooled down and ground into powder. The beef flavor powder was kept in a sealed aluminium foil bag at room temperature before analysis.

2.3 Physical properties of beef flavors

The moisture content of the samples was determined following AOAC 2005 [12]. Bulk density was measured by weighing 5 g of sample in a cylinder and placing the cylinder on a shaker for 5 min [13] and finally calculating mass/volume. Solubility of the samples was determined as follows: addition of 10 mL of water to 1 g of the sample, heating to 65-70°C, and stirring for 5 min before centrifugation at 3,000 rpm for 10 min[13]. The supernatant was then dried in an oven at 105°C for 5 h and the solid weight was determined. % Solubility was the percentage of the sample that could be dissolved in water. The color of the beef flavor powder was measured as L*, a* and b* by using a Hunter lab [13].
2.4 Sensory test
Sensory acceptability of the beef flavors extruded at various temperatures and the control was carried out by 40 panelists who are students at KMUTNB and 10 panelists who are staff members at Mighty International Co., LTD. The Hedonic test with a 9-point scale was applied for evaluating odor, taste, and overall acceptability of the beef flavors at 1% solution (w/v), which was served to the panelists.

2.5 GC-MS analysis
Volatile compounds of the beef flavors from extrusion with temperature of zone 1 at 100°C, as well as the control, were analysed using GC-MS [14]. Beef flavor at 3 g was added to 5 mL of distilled water in a vial for the headspace technique. The samples were heated to equilibrium conditions at 60 °C for 30 min with the solid phase microextraction method (SPME fiber, 50/30 μm DVB/Carboxen TM/PDMS Stable FlexTM). Desorption was performed at 220°C for 5 min. The GC-MS (MSD 5973N, Agilent Technology, Inc. Palo Alto, CA, USA) column was a capillary column DB-1MS (30 m x 0.250 mm ID x 0.25 μm film thickness). Oven initial temperature and inlet temperature were set at 35°C and 220°C, respectively. The gas flow rate was controlled at 1 mL/min with the split mode at splitless and scan mass was carried out at 25-500 m/z.

3. Results and Discussion

3.1 Physical properties of beef flavors
The moisture content, bulk density, and solubility of the beef flavor powder obtained from direct extrusion and compared to the control are shown in table1. Results show that the moisture content of extruded beef flavors were 4.78-5.08%, which are not significantly different, but the moisture content of the control was only 3.43%. The bulk density of all samples from extrusion was higher than the control, due to the fact that pressing and mixing under pressure in the extruder may have led to higher bulk density [15]. Neither the extruded samples nor the control showed any significant differences in the percentage of solubility. Solubility is an important characteristic of flavoring agents for product development.

Table 1. Properties of beef flavors extruded at different barrel temperatures.

| Temperature of zone 1 (°C) | Moisture (%) | Bulk density (g/cm³) | Solubility ns (%) |
|---------------------------|--------------|----------------------|-------------------|
| 80                        | 5.08 ± 0.02a | 0.69 ± 0.02a         | 92.34 ± 1.96a     |
| 100                       | 4.79 ± 0.29a | 0.70 ± 0.01a         | 91.29 ± 1.74a     |
| 120                       | 4.78 ± 0.69a | 0.71 ± 0.01a         | 90.52 ± 1.10a     |
| Control                   | 3.43 ± 0.12b | 0.63 ± 0.01b         | 92.30 ± 1.87b     |

a, b means with different letter in the same column are significantly different (p<0.05)

Figure 1 shows the beef flavors produced by extrusion with zone 1 temperature at different levels compared to commercial product produced by the traditional method. In general, the Maillard browning reaction yields a colored compound called melanoidins [16]. The melanoidin varies in color from brown to black. Results of L* values of the flavor product extruded at 80°C of zone 1 were similar to the L* value of the control, while the color of extruded flavor products at 100 and 120°C showed similar L* values (table 2). The results indicate that, in this experiment, Maillard browning can be controlled by the extrusion temperature of zone 1.
Table 2. Color of beef flavors extruded at different barrel temperatures.

| Temperature of zone 1 (˚C) | L*         | a*           | b*          |
|---------------------------|------------|--------------|-------------|
| 80                        | 31.48 ± 0.25<sup>a</sup> | 10.00 ± 0.18<sup>b</sup> | 13.48 ± 0.13<sup>b</sup> |
| 100                       | 19.96 ± 0.44<sup>b</sup> | 9.06 ± 0.27<sup>c</sup> | 7.30 ± 0.03<sup>c</sup> |
| 120                       | 19.63 ± 0.42<sup>b</sup> | 8.63 ± 0.15<sup>d</sup> | 7.10 ± 0.09<sup>c</sup> |
| Control                   | 31.90 ± 0.42<sup>a</sup> | 7.22 ± 0.09<sup>a</sup> | 12.09 ± 0.17<sup>a</sup> |

<sup>a, b</sup> mean with different letter in same column are significantly different (p<0.05)

![Figure 1](image)

**Figure 1.** Beef flavors produced by extrusion with zone 1 temperature at 80°C, 100°C, and 120°C, and the traditional method.

3.2 Sensory evaluation
The Maillard reaction occurred in the extruder barrel both in the barrel zone 1 and 2 generated the characteristics of beef flavor as shown in table 3. Generally, the brown color and beef flavor/taste of the samples from the extrusion with temperature of zone 1 at 100°C and 120°C were accepted with higher scores than the control and the extrusion at 80°C of the zone 1.

Table 3. Sensory evaluation of beef flavors extruded at different barrel temperatures and the control.

| Temperature of zone 1 (˚C) | Odor         | Taste        | Overall acceptance |
|---------------------------|--------------|--------------|--------------------|
| 80                        | 5.52 ± 1.11<sup>bc</sup> | 5.78 ± 1.25<sup>b</sup> | 6.14 ± 1.08<sup>b</sup> |
| 100                       | 6.12 ± 0.96<sup>a</sup> | 6.46 ± 1.11<sup>a</sup> | 6.66 ± 1.06<sup>a</sup> |
| 120                       | 5.96 ± 1.29<sup>ab</sup> | 6.34 ± 1.33<sup>a</sup> | 6.48 ± 1.18<sup>ab</sup> |
| Control                   | 5.34 ± 1.15<sup>c</sup> | 5.56 ± 1.03<sup>b</sup> | 6.12 ± 1.30<sup>b</sup> |

<sup>a, b</sup> mean with different letter in same column are significantly different (p<0.05)

3.3 Volatile compounds by GC-MS analysis
Aroma is formed during non-enzymatic browning. The important intermediate reaction of dicarbonyl compounds, mainly osones and deoxyosones, is generated via Strecker degradation [16]. Examples of important aroma compounds are methanethiol, methylpropanal, and 3-methylbutanal [16]. In this
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In this study, the important volatile compounds contributing to beef flavors are methanethiol and nonanal (table 4).

Table 4. Volatile compounds detected in beef flavors by traditional method (control) and extrusion method (Barrel temperature of zone 1 at 100°C).

| Volatile compounds                     | Control     | Extruded sample | Odor description                        |
|----------------------------------------|-------------|-----------------|-----------------------------------------|
| 1) Methanethiol*                       | ×           | ×               | Stewed beef, Ground beef                |
| 2) 2-methyl-furan                      | ×           |                 | Chocolate                               |
| 3) 2-Propenal                          | ×           |                 | Pungent                                 |
| 4) Dimethyl disulfide                   | ×           | ×               | Sulfur                                  |
| 5) Acetic acid                         | ×           | ×               | Pungent                                 |
| 6) Formic acid                         | ×           |                 | Pungent                                 |
| 7) 3-(methylthiol)-Propanal            | ×           | ×               | Soy sauce                               |
| 8) Benzaldehyde                         |             | ×               | Almond, musty                           |
| 9) Dimethyl trisulfide                  | ×           | ×               | Garlic, rotten cabbage                  |
| 10) 2-[(Methylthio)methyl]-Furan        | ×           | ×               | Smoke                                   |
| 11) 1-methyl-1H-pyrrole-2-carboxaldehyde | ×       |                 | Nuts                                    |
| 12) 1H-Pyrrole-2-carboxaldehyde        | ×           | ×               | Tea, coffee                             |
| 13) Nonanal*                           | ×           |                 | Ham, beefy                              |
| 14) 2-Coumaranone                      | ×           |                 | Flavor                                  |
| 15) 1,6-Dimethyl– cyclohexene          |             | ×               |                                        |
| 16) 1-(1H-pyrrol-2-yl)-ethanone        | ×           | ×               | Popcorn                                 |
| 17) 3,5,5-Trimethyl-2-cyclopenten-1-one | ×       |                 | Sweet, osmanthus                        |
| 18) 6-Chloro-2H-pyran-2-one            | ×           | ×               |                                        |
| 19) Furfurlyden.-alpha.-               | ×           |                 |                                        |
| 20) Furymethylamine.-alpha.            |             |                 |                                        |
| 21) 1-(2-furanyl)methyl)-1H-Pyrrole    | ×           | ×               | Roasted chicken                         |
| 22) 2,4-bis(1,1-dimethylethyl)-Phenol  | ×           |                 |                                        |
| 23) 2-Methylmethylene-cyclohexane      | ×           |                 |                                        |

*Key compounds of beef flavors [14].

The Maillard reaction is mainly responsible for the large number of heterocyclic compounds which were found in the volatiles of cooked meat and are responsible for savory, roast, and boiled flavors.
Furanthiols and furan sulfides and disulfides are important flavor compounds, and are responsible for characteristic meaty aromas [4, 21]. Many compounds that occur contribute to beef flavors. Beef flavors can also be generated through an extrusion process because heating at high temperature can lead to the Maillard reaction in the barrel. A number of volatile compounds detected in beef flavor control and extruded beef flavors using 100°C of barrel zone 1 varied. Sixteen volatile compounds were detected in the control sample, while the extruded sample resulted in only thirteen volatile compounds. The key compound for beef flavors, methanethiol, was found in the samples from both processes. Methanethiol, one of the characteristic compounds that impact the odor of stewed beef juice [18], were found in cooked ground beef while 2-furancarboxaldehyde, 3-(methylthiol)-propanal, and 2-[(methylthio)methyl]furan were detected in beef flavors [17,19] from both the extrusion and the control.

Nanonal, the volatile compound with beefy and ham odor [14], was only detected in the extruded flavors. The differences of volatile compounds found in beef flavor powder from the traditional method were 1-(2-furanylmethyl)-1H-pyrrole, contributing to roasted chicken, 1-(1H-pyrrole-2-yl), ethanone, which gives a popcorn flavor, while nonanal contributes ham and beef, and 1-Methyl-1H-pyrrole-2-carboxaldehyde, which gives a nutty flavor. The sulfur volatile compounds dimethyl disulfide and dimethyl trisulfide were also found in the flavors from both extrusion and the control samples. Dimethyl trisulfide can be detected in garlic and rotten cabbage [10]. Dimethyl disulfide can be detected in seafood such as mussels and fish [20]. Aliphatic thiols, sulfides, and disulfides have been reported in boiled and roast beef or meat. Heterocyclic compounds with 1, 2, or 3 sulfur atoms in 5- and 6-member rings (e.g. thiophenes, trithiolanes, trithianes) are much more prevalent in boiled meat than in roasted meat [4].

4. Conclusion

Beef flavors can be produced by direct extrusion from the reaction of amino acid and reducing sugars in an extruder barrel at high temperature and in a short period of time. The physical properties in terms of appearance, color, and solubility are comparable to those of a commercial product. The extruded beef flavors resulting from a zone 1 temperature of 100°C and 120°C obtained higher sensory scores than the sample extruded at 80°C and the commercial product produced by the long traditional process method, in terms of odor, taste and overall acceptability. Many volatile compounds found in the Maillard reaction were also detected in the extruded beef flavors. Though there are some differences in the flavor profiles between the two methods, the product obtained from extrusion obtained higher overall acceptance than the control. The optimum extrusion temperature of zone 1 was 100 and 120°C. Therefore, extrusion could be potentially used for the production of beef flavors instead of the traditional method.

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