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Vacuum frying of breaded shrimps

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ABSTRACT

Vacuum frying (VF) was tested as an alternative technique to produce high-quality fried food. This study investigated the effects of oil temperature on the moisture loss, oil uptake, texture, color, and acrylamide content of vacuum-fried versus atmospheric-fried breaded shrimps. The moisture loss and oil absorption of breaded shrimps during VF were significantly affected ($p < 0.05$) by oil temperature. Oil absorption was directly proportional to moisture loss during VF. The oil absorption of breaded shrimps during VF increased with increasing temperature for the same frying time. After 10 min of frying, the oil contents of breaded shrimps fried at 80 °C, 100 °C, and 120 °C under vacuum conditions were 0.20 ± 0.013, 0.23 ± 0.012, and 0.25 ± 0.019 $g_{oil}/g_{dry\ solid}$, respectively. These values were significantly lower than those (0.32 ± 0.019 $g_{oil}/g_{dry\ solid}$) obtained under atmospheric conditions (170 °C). VF effectively decreased the acrylamide content of breaded shrimps. Furthermore, breaded shrimps with desirable color and low hardness can be produced using VF. These results indicate that VF is a feasible alternative technique to produce high-quality breaded shrimps.

1. Introduction

Shrimp is an important aquatic product that is rich in protein, mineral, and vitamins (Heu, Kim, & Shahidi, 2003; Mohebbi, Akbarzadeh-T, Shahidi, Moussavi, & Ghoddusi, 2009). However, it is highly perishable, and its shelf-life at room temperature is very short (Wu, 2014). Thus, it is often processed into various products with long shelf-life. Breaded shrimp is a widely consumed shrimp product because of its high nutritious value, attractive appearance, unique flavor, and convenience, especially in developed countries. At present, deep-fat frying is the main cooking style of breaded shrimp. However, numerous studies have revealed that traditional deep-fat-fried breaded shrimp contains a mass of fat, which is a key dietary contributor to obesity and coronary heart disease (Browner, Westenhouse, & Tice, 1991; Sothornvit, 2011).

In recent years, consumers are increasingly demanding healthy alternatives to fried food; such alternatives should contain less fat and more original attributes than fried food (Ouchon & Pyle, 2004). Compared with traditional atmospheric frying (AF), vacuum frying (VF) offers a better solution to produce healthy and high-quality products (Granda, Moreira, & Tichy, 2004). It is reported that vacuum frying can reduce the oil content of fried products in some articles, so vacuum frying can be as a possible frying method to produce fried products with less oil content instead of traditional frying. The low temperature and oxygen content during the process can preserve the natural color and flavors of the product and protect the quality of oil in the bath (Garayo & Moreira, 2002). The acrylamide content of fried products can also be decreased (Granda & Moreira, 2005).

In recent years, VF studies have focused on fruits and vegetables. Garayo and Moreira (2002) used paper towels to remove excess oil from the surface of potato chips after removing the product from the fryer. They found that potato chips fried under vacuum (~3.12 kPa) show lower oil content (30% less), slightly softer texture, and lighter color than those fried under atmospheric conditions (165 °C). Granda and Moreira (2005) studied the kinetics of acrylamide accumulation in potato chips fried under vacuum and atmospheric conditions at different frying temperatures. They concluded that VF can significantly reduce acrylamide content compared with AF.

Even though frying is a conventional process in food production, most research found in the literature is related to AF. Information regarding the effect of VF on the moisture content, oil content, color, texture, and safety of shrimp products is lacking.

Abbreviations: AACC, American Association of Cereal Chemists; AOAC, Association of Official Analytical Chemists; HPLC, high performance liquid chromatography; MS, mass spectrometry; VF, vacuum frying; AF, atmospheric frying.

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This research aims to investigate the effect of frying technologies and conditions on the moisture loss, oil uptake, and other characteristics (such as color, texture, and acrylamide content) of breaded shrimp.

2. Materials and methods

2.1. Raw material

Shrimps (*Litopenaeus vannamei*) with average sizes of 52 shrimps/kg to 56 shrimps/kg were obtained from a local seafood wholesale market (Xiashan, Zhanjiang, China). They were immediately covered in ice cubes and quickly transported to the laboratory. Upon arrival, they were washed with ice water and kept frozen at −20 °C prior to use.

Wheat flour (0.138 g/g moisture, 0.121 g/g protein, 0.009 g/g crude fat, and 0.005 g/g ash), sugar, salt, and soybean oil were purchased from Wal-Mart (Zhanjiang, China). Sodium tripolyphosphate and soy protein isolate (0.813 g/g moisture, 0.091 g/g protein, 0.004 g/g crude fat, and 0.001 g/g ash) were purchased from Zhengzhou Chenyang Chemical Industry Co., Ltd. (Zhengzhou, China). Pre-dust and breadcrumbs were purchased from Niuliwei Food Co., Ltd. (Beijing, China).

2.2. Sample preparation

Frozen shrimps were defrosted in a refrigerator at 4 °C overnight. The thawed samples were deheaded, peeled, and deveined, and the tails were stored. The abdominal segments of the shrimps were exscinded with a knife from the back to the tails, and the depth of slits accounted for approximately 90% of the abdominal segments. The shrimps were washed with ice water, soaked for 40 min in a saline solution that consists of salt and sodium tripolyphosphate at 1.5 g/L, rinsed with cold water, and then placed on a stainless steel screen for 5 min to remove excess moisture from the surface of shrimps. Each sample was weighed before coating and found to have a uniform range of (0.012 ± 0.002) kg. The shaped samples were coated by the pre-dusts and then immersed into a beaker containing a batter suspension for 30 s. The suspension consisted of wheat flour (0.092 kg), soy protein isolate (0.008 kg), sugar (0.010 kg), salt (0.005 kg), and purified water (192 mL). The samples were allowed to drip for 15 s and then coated with breadcrumbs. The coated shrimps (breaded shrimps) were stored in a refrigerator at −18 °C for 24 h. The completed process steps of sample preparation are shown in Fig. 1.

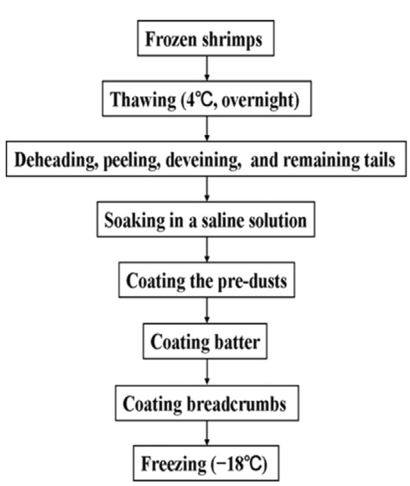

Fig. 1. Flow diagram of breaded shrimp production.

2.3. VF experiments

Before frying, the frozen breaded shrimps were removed from the refrigerator and thawed at room temperature for 2 min. The experiments were performed using a vacuum fryer (DG 350, Shenzhen grand electronic machinery co., Ltd, China) available at the Sericulture and Agri-food Research Institute, Guangdong Academy of Agricultural Sciences, China. The electrical appliance consisted of a low-temperature vacuum-frying chamber with an inner basket, a membrane vacuum pump to provide vacuum to the vessel, and a heating system controlled by a temperature probe.

Three levels of oil temperature for VF (80 °C, 100 °C, and 120 °C) were considered, the vacuum pressure was −0.088 MPa to 0.090 MPa (Relative pressure), and the boiling point of water was approximately 50 °C at the working pressure. The frying times investigated were 1, 2, 3, 4, 5, 6, 8, and 10 min. The vacuum vessel was set to the target temperature and allowed to operate for 1 h before frying started. The volume of oil used was 10 L. Fresh soy oil was used in all experiments at each temperature.

Ten samples were fried in each frying batch to reduce temperature fluctuation during frying. Once the oil temperature reached the target value, the breaded shrimps were placed into the basket, the lid was closed, and the vessel was evacuated. When the pressure in the vessel achieved vacuum, the basket was submerged into the hot oil. Once the products were fried, the basket was raised, and the vessel was pressurized up to atmospheric pressure. The lid of the vessel was opened, and the breaded shrimps were removed from the basket. The samples were allowed to cool to room temperature (25 °C) and then dried with paper towels to remove excess surface oil (Da Silva & Moreira, 2008).

2.4. AF experiments

AF experiments were conducted using the same equipment and procedure, but the vacuum pump was switched off. To compare the effects of AF and VF on the quality and frying rate of breaded shrimps, we used an oil temperature of 170 °C, a common temperature used in breaded shrimp frying.

The frying times investigated were similar to those for vacuum treatments. The atmospheric fryer was set to the required frying temperature and maintained for 1 h to ensure that the oil temperature was constant. After the frying time, the breaded shrimps were removed from the fryer and cooled to room temperature. Finally, the samples were dried with paper towels to remove excess oil.

2.5. Moisture content

Moisture content analysis was performed based on the American Association of Cereal Chemists (AACC) standards (1986). The whole fried breaded shrimps were dried in an oven (Yiheng Co., Ltd., Shanghai, China) at 105 °C for 24 h. The samples were cooled in desiccators, and moisture contents were determined by obtaining the difference in weight on a dry basis. The moisture contents of the breaded shrimps were measured before and after frying.

2.6. Oil content

The total oil content of ground breaded shrimps was gravimetrically determined by Soxhlet extraction with petroleum ether (AOAC, 1995).