Contents lists available at ScienceDirect

Food and Bioproducts Processing

journal homepage: www.elsevier.com/locate/fbp

Low oil French fries produced by combined pre-frying and pulsed-spouted microwave vacuum drying method

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ARTICLE INFO

Article history:
Received 20 November 2014
Received in revised form 12 April 2016
Accepted 25 April 2016
Available online 30 April 2016

Keywords:
French fries
Vacuum frying
Pulsed-spouted microwave- vacuum drying
Oil content
Texture
Microstructure

ABSTRACT

French fries were prepared by a combined method of pre-frying and pulsed-spouted microwave vacuum drying (PSMVD). The impact of pre-frying and PSMVD on the quality (oil content, color, texture, microstructure and shrinkage in volume) of French fries was studied and the sample was compared with that of only vacuum fried ones. The results indicated that the French fries prepared by the combined method had lower oil content (25%, db) than that of vacuum-fried sample (40%). Other property analysis also showed that the combined technique processed samples exhibited comparable food texture and color to that of vacuum fried samples, and had a porous microstructure with relatively smaller pore size. It was concluded that the combined method of pre-frying and PSMVD could be an alternative method to produce high quality French fries with low oil content.

1. Introduction

French fries are worldwide popular food thanks to their pleasant taste and typical flavor (Van Loon et al., 2005). French fires generally produced by immersion in edible oil or fat at a temperature above the boiling point of water. It is a rapid process of simultaneous heat and mass transfers, which can be used as a drying operation, resulting in flows in opposite directions of water vapor (bubbles) and oil at the surface of the piece. However, this frying process always leads to a high oil content of about 40% in the French fries (Gupta et al., 2010), which is not considered a good property as too much fat intake would have negative impact on human health (Krokida et al., 2001a). Customers demand for low-fat even fat-free products with a long time storage has been the driving force of the food industry to produce lower oil content fried potatoes that still retain desirable texture and flavor (Song et al., 2007a).

Vacuum frying is defined as a frying process which is carried out under pressures well below atmospheric levels (Andrés-Bello et al., 2011). Due to the lowered pressure, the boiling points of both the oil and the moisture in the foods are also lowered. This offers some advantages: (1) reduced oil

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http://dx.doi.org/10.1016/j.fbp.2016.04.008
0960-3085/

content in the fried product, (2) preservation of natural color and flavor of the product due to the low temperature and oxygen content during the process, and (3) reduced adverse effects on oil quality (Song et al., 2007b). In addition, the frying process significantly affects the microstructure and porosity of the dried products (Dehnath et al., 2003). During the vacuum frying, water evaporates very rapidly from the surface of the food and the locations from which moisture is driven out become dry and creates porous microstructures, which benefits to the crisp texture of the product.

Lulai and Orr (1979) reported that the most clearly defined factor influencing oil uptake during fried chips production is the initial solids content of the tubers. Furthermore, Moreira et al. (2009) found that the rate of oil uptake, but not the final oil content, was greatly affected by the frying conditions. More specifically, it had been demonstrated that using several pretreatment (like osmotic dehydration, coating and pre-drying) before frying could effectively reduce the oil content. For instance, Bunger et al. (2003) reported that soaking with 3% NaCl solution for 50 min significantly reduced oil uptake from 0.13 to 0.10 g oil/g dry matter. But, it also was reported that the decrease in oil absorption using osmotic dehydration pretreatment was attributed to the increase in solids content occurring during the osmotic dehydration process rather than a reduction in the amount of oil taken up (Moreno and Bouchon, 2008). So it has been debated recently that the importance of selecting an adequate basis to carry out comparisons properly. Moreover, even if the oil content had been significantly reduced in such products with pretreatment, they still had not met the requirement of low-fat content fried potatoes. Moreover, the excessive osmotic dehydration and pre-drying will lead to destruction of the taste and texture of French fries.

To further improve the French fries' favorable color while reduce the oil content, combined technology such as by introducing microwave finishing after pre-frying was reported (Porter et al., 1973). The combination of microwave drying significantly increases the heating rates and reduces the drying time (Salazar-González et al., 2012; Zhang et al., 2006), which in turn reduces the frying time and oil content while improves the product quality. However, the major drawback associated with microwave heating is the non-uniform temperature distribution, resulting in hot and cold spots in the heated product, which not only affects the quality but also raises the issue of food safety (Vadivambal and Jayas, 2010). Recently, a new equipment of pulsed-spouted microwave vacuum dryer (PSMVD), invented in our laboratory, was used to solve this problem (Zhang and Wang, 2012). The added "pulsed spout" feature in the microwave vacuum dryer provided a more uniform temperature distribution in the dryer when compared with those conventional rotating turntable microwave vacuum dryer, and consequently the product quality was significantly improved (Wang et al., 2013).

The objective of this work was to produce lower oil French fries by combining pre-frying with PSMVD. The effect of this new method on the product quality was compared with the vacuum frying process.

2. Materials and methods

Potatoes were purchased from a local market in Wuxi, China, and stored in a refrigerator at 5 °C until used. Palm oil (Jia-li Co. Ltd., Lianyungang, China) was also purchased from the local market.

2.1. Pretreatment of French fries

Fresh potatoes were washed, peeled and cut into 10 mm × 10 mm × 40 mm slices with a manual potato cutter. The potato slices were blanched in a water bath at 90 ± 1 °C for 5 min followed by cooling under running tap water for 1 min. Excess water was removed by draining on tissue papers. Finally, the potato slices were frozen in a refrigerator at −18 °C prior to frying.

2.2. Vacuum frying (VF)

A lab-scale vacuum fryer equipped with a centrifuge (Nan Feng Company, Wuxi, China) was used to prepare the vacuum-fried samples. The fryer was filled with 5 L of palm oil as the frying medium.

The frying temperature and vacuum pressure was set at 90 ± 1 °C and 16 kPa, respectively. Six batches of 100 g potato slices each, after the pretreatment, were fried for 5, 10, 15, 20, 25 and 30 min. After frying, the potato slices were centrifuged at 300 rpm for 8 min under vacuum to remove the frying oil. The centrifuged potato slices were transferred to a plastic bag and then put into the equipment of PSMVD in 3 min to prevent oxidation. All experiments were conducted in triplicate.

2.3. Pulse-spouted microwave vacuum drying (PSMVD)

A newly developed experimental apparatus, which was explained in details in a recent patent (Zhang and Wang, 2012), was used for pulse-spouted microwave vacuum drying (Fig. 1). Different from the conventional rotating turntable microwave vacuum dryer, the PSMVD apparatus includes a pulsed-spouted system with a set of adjustable air flow and distributive unit as well as a set of air handing units at the bottom of drying chamber (Wang et al., 2013). A schematic diagram of the equipment was present in Fig. 1.

During the pulse-spouted microwave vacuum drying, the vacuum-fried samples were spouted at a specific time interval so as to ensure the air can flow periodically into the duct drying chamber via controlling the electromagnetic valve (2 s on/60 s off). The pressure was fluctuated within the drying chamber from 11 to 18 kPa.

From our preliminary experiments, potato slices par-fried 15 min (moisture content of about 18.5% and oil content of about 31.94%) (dry base, db), was selected for PSMVD to a final moisture content of about 3%. The selected par-fried samples were subjected to pulse-spouted microwave vacuum drying with different microwave power levels of 10, 15, 20 W/g sample (Table 1). At the end of each process, dried samples were packed in separate plastic bags and kept in a desiccator for further quality analysis.

2.4. Determination of moisture content

The moisture content of the samples was measured by using the oven method (Fan et al., 2006). Approximately 3 g of ground French fries were placed in the oven and dried at 102 ± 3 °C until the mass of the sample did not change further.

2.5. Determination of oil content

The oil content was determined by using the Soxhlet extraction method (Fan et al., 2006). Ground sample was oven-dried