Food Hydrocolloids 28 (2012) 53–58

Contents lists available at SciVerse ScienceDirect

Food Hydrocolloids

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

Cross-linking of wheat starch improves the crispness of deep-fried battered food

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ARTICLE INFO

Article history:
Received 23 February 2011
Accepted 6 December 2011

Keywords:
Crispness
Deep frying
Moisture
Oil reduction
Sound
Batters
Starch
Viscosity

ABSTRACT

Wheat starches with different degrees of cross-linking were used to study the effect of starch gelatinization in the batter and crust characteristics of deep-fried battered food. Pasting properties, viscosity and batter pick up as well as moisture and oil content and crispness of the fried crusts were evaluated. In batters prepared with a constant solids/water ratio, the cross-linked starches increased batter viscosity and consequently the batter pick up. Batters, with comparable viscosity were prepared by varying the solid/water ratio which gave the same batter pick up.

The pasting properties of cross-linked starches showed that the higher the cross-linking the more resistant was the starch to gelatinization and granule disintegration. In batters with a constant solids/water ratio, batter with high cross-linked starch had more water loss during frying. Cross-linked starches had lower moisture content after storage and less oil was retained after frying. Crispness, measured instrumentally as sound intensity, was the highest for the high cross-linked starch at 1 and 20 min after frying.

Batters prepared with the same viscosity were used to study the effect of cross-linked starches when the pick up was the same. To obtain comparable viscosities between the batters, the batter with native starch was prepared using the lowest mixing water content and the one with high cross-linked starch with the highest. The batter with the high cross-linked starch, although it had the highest addition of water, had the best crispness after frying.

In conclusion, high cross-linking of wheat starch enhances crispness perception of deep-fried battered food.

1. Introduction

Batter coating of fried foods is common practice in the food industry. It is used for the preparation of, for example, French fries, chicken nuggets, vegetables and fried fish sticks. Deep frying batter is defined as a liquid mixture comprised of water, flour, starch and seasonings into which food products are dipped prior to cooking (Suderman & Cunningham, 1983). This technique usually provides the battered food with a crispy texture and characteristic flavour. Current research in this area is directed towards obtaining products with low oil content and high textural characteristics such as crispness (Primo-Martín & van Deventer, 2011; Primo-Martín et al., 2010).

Starch and modified starches have been used as batter ingredients to improve batter texture (Fiszman & Salvador, 2003; Miyazaki, Van Hunga, Maeda, & Morita, 2006) and to decrease the oil content of the fried batters (Ahamed, Singhal, Kulkarmi, & Palb, 1997). For example, modified starches with high amylose content have good film-forming properties that help to reduce oil absorption by creating a barrier against oil uptake (Fiszman & Salvador, 2003). Recently, chemically modified starches such as cross-linked starches have been used for various types of prepared foods to improve their quality characteristics such as crispness (Han, Lee, & Lim, 2007; Van Gijssel, Meima, & Buwalda, 2003). Starch can be chemically cross-linked using phosphorus oxychloride, sodium trimetaphosphate or adipic anhydride. These newly created chemical bonds reinforce the native granule structure (Yook, Pek, & Park, 1993) and prevent swelling and gelatinization of starch granules and, therefore, granule disruption.

The composition of the batter has a significant effect on the amount of coating pick up (Altunakar, Sahin, & Sumnu, 2006), and the characteristics of the crust after deep frying such as moisture, oil content and crispness. Cunningham and Tiede (1981) showed that as batter viscosity increased, the amount of batter pick up also increased. Batter viscosity directly influenced coating pick up when different proteins or flours were used in the batter formulation (Dogan, Sahin, & Sumnu, 2005a, 2005b). Naruenartwongsakul, Chinnan, Bhumiratana, and Yoovidhva (2008) showed that, by

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doi:10.1016/j.foodhyd.2011.12.002

using batters with either controlled viscosity (at 1200 cP) or controlled water content, the microstructure of fried batters was influenced by the viscosity and by the water content of the batter.

The aim of this study was to evaluate the effect of the degree of cross-linking on batter characteristics such as viscosity and pasting behaviour and crust characteristics such as moisture and oil content and crispness. However, because the addition of additives such as cross-linked starches affects the viscosity of the batters and therefore influences batter pick up and final crust properties, the objective of this study was to unravel the effect of the degree of cross-linking on batter and crust properties by using (a) batters with constant solids/water ratio and (b) batters with constant viscosity.

2. Materials and methods

2.1. Materials

Zeemeeuw, a commercial wheat flour purchased from Meneba (Rotterdam, The Netherlands), was used to prepare the batter. According to the manufacturer, the composition of the wheat flour was 10% (dry basis [d.b.]) protein, 86% (d.b.) starch, and 11.5% moisture.

Four different types of wheat starches: native, low cross-linking, medium cross-linking and high cross-linking, were kindly prepared by Avebe (Veendam, The Netherlands).

The oil used to deep fry the battered food was non-hydrogenated peanut oil (Romi Smilfood BV, Heerenveen, the Netherlands). The food matrix was minced pork meat obtained from Encebe Vleeswaren (Boxtel, The Netherlands).

2.2. Batter preparation

2.2.1. Batters with constant solids/water ratio

The composition of the batter was 331 g wheat flour, 331 g native wheat starch, 20.25 g leavening agent (Backpulver, Dr Oetker Food Service, Ede, The Netherlands), 13.5 g salt and 625 mL of tap water. To study the effect of the cross-linked starches, native wheat starch was replaced by equal amounts of wheat starches with a low, medium or high degree of cross-linking. The batter was prepared by mixing all ingredients for 3 min using an N-50 mixer (Hobart, North York, Ontario, Canada) at speed 1. Before use, the batter was conditioned for 1 h at room temperature (25 ± 1 °C).

2.2.2. Batters with comparable viscosity

The composition of the batter was 331 g wheat flour, 331 g native or cross-linked wheat starch, 20.25 g leavening agent and 13.5 g salt. The amount of water added was: 580, 615, 625 and 630 mL for the native starch, low, medium and high cross-linked starches, respectively. The batter was prepared as described above for the batters with constant solids/water ratio.

2.3. Flow behaviour of the batters

The flow behaviour of the batters was investigated at 25 °C using small concentric serrated cylinders in a AR 2000 rheometer (TA instruments, Etten-Leur, The Netherlands). The apparent viscosity of the batters was measured as a function of the shear rate over the range 1–100 s^{-1}. Measurement time per shear rate step was 10 s.

2.4. Starch pasting properties

The pasting properties of the batters were characterized by using a Brabender micro-visco amylograph (Model 803202, C.W. Brabender Instruments, Inc., Duisburg, Germany) at a speed of 75 rpm. Batter (25 mL) was diluted with 90 mL of water before measuring and then heated from 30 °C to 95 °C at a rate of 3 °C/min, held at 95 °C for 15 min, next cooled down to 30 °C at a rate of 3 °C/min and held at 95 °C for 15 min. Pasting temperature, peak viscosity, breakdown and setback were analyzed from the graphs obtained.

2.5. Preparation of deep-fried battered food

Meat sausages were prepared using the minced pork meat and were cooked for 2 h at 85 °C. Next, they were cooled down for 2 h in streaming cold water. The sausages were packed in a plastic bag under vacuum and stored at −20 °C.

To prepare the battered meat, pieces of thawed meat sausage (9-mm thick, 40-mm diameter) were pre-dusted with wheat flour, immersed in the batter, and allowed to drip for 20 s. The battered food matrices were pre-fried in peanut oil at 180 °C for 1 min using a 14.0-kW fryer (Frymaster H14-2, Shreveport, LA, USA). They were allowed to cool for 10 min, wrapped in aluminium, packed in a double plastic bag and then frozen at −20 °C for 1 week. The samples were final fried in peanut oil at 180 °C for 3 min (Primo-Martín & van Deventer, 2011).

After the final frying they were characterized at 1 and 20 min after frying and storing at 40% relative humidity and 22 °C (Weiss SB 11300 climate cabinets, Weiss Enet Industrietechniek, Tiel, The Netherlands).

2.6. Batter pick up

The amount of batter adhering to the sample during coating before frying was considered as the batter pick up. It was calculated as the weight of the coating picked up by the piece of meat divided by the weight of the uncoated piece of meat and multiplied by 100. To avoid effects of the batter dripping off during measurement of the pick up, the batter was allowed to drip for 20 s after coating and then the coated piece of meat was weighed. Any dripping happened during this 20 s.

2.7. Moisture content

The moisture content of the crust of the deep-fried battered food 1 and 20 min after final frying was determined using a dry oven method. The crusts were placed in an oven at 105 °C for 24 h and the moisture content was calculated from the difference in weight determined before and after oven drying. Four replicates per sample were used. These samples were then used to determine the oil content. Results were expressed as % of oil-free dry solids.

2.8. Oil content

The oil content of the dried and ground crusts was determined by extraction with petroleum ether using a 2050 Soxtec Avanti 2050 extraction system (Foss Tecator, Sweden) and expressed as % of oil-free dry solids. Four replicates per sample were used.

2.9. Scanning electron microscopy

Crusts of deep-fried battered food containing native, low cross-linked, medium and high cross-linked wheat starch from batters prepared with a constant solids/water ratio were defatted using