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Partial least-squares regression study of the effects of wheat flour composition, protein and starch quality characteristics on oil content of steamed-and-fried instant noodles

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Abstract

Steamed-and-fried instant noodles represent a fast growing product category; however, concern has been raised about high residual oil content by both consumers and manufacturers. To understand how wheat flour characteristics affect the oil content of instant noodles, samples of five Iranian hexaploid landraces, five US/Canadian samples, and seven local commercial wheat flours were analyzed for composition, protein and starch quality, and noodle-making quality. Partial least-squares regression (PLS) analysis between composition, protein quality properties and wheat starch gel properties (independent variables, *X*) and oil content of instant noodles (dependent variable, *Y*) resulted in a model that could explain 76.3% of the variability with a cross-validated correlation coefficient of 58.2%. PLS regression coefficient analysis showed that protein content and protein quality were the most important factors, and were negatively correlated with oil content of instant noodles. Starch quality properties, gel hardness, gumminess and chewiness as well as pasting properties were other important contributors. Starch gel hardness, gumminess and chewiness were positively correlated with oil content of instant noodles, while pasting properties were negatively correlated.

Keywords: Steamed-and-fried instant noodles; Oil; Protein and starch contents; Protein and starch quality; Partial least-squares regression

1. Introduction

With nearly 40% of wheat being processed into noodle products in Asian countries (Crosbie, 1991), the consumption of wheat noodles is second only to bread globally (Ding and Zheng, 1991). The instant noodle market is growing fast in Asian countries, and is gaining popularity in the Western market (Shin and Kim, 2003; Yu and Ngadi, 2004). Depending on the method of dehydration, instant noodles can be divided into fried and non-fried types (Wu et al., 1998). Fried instant noodles are made by a continuous steaming and frying process that gelatinizes the starch and quickly dehydrates the noodles. The resulting product has a porous spongy structure and an excellent flavour (Rho et al., 1986; Wu et al., 1998). Non-fried instant noodles can be dehydrated after expansion from a tight non-expanded structure, or using high-temperature expansion to produce a porous, honey-comb-like structure—the expanded type (Wu et al., 1998).

Abbreviations: AD, adhesiveness (the total negative area between the first and the second peak, g/s); area, integral area beneath the mid line from time zero to the peak time; BD, breakdown (peak viscosity minus hot paste viscosity); CH, chewiness (gumminess × springiness); CO, cohesiveness (the ratio of the positive force area between the second and first compression); FV, final viscosity (the viscosity at the end of the test after cooling to 50 °C and holding at this temperature); GU, gumminess (hardness × cohesiveness); HD, hardness (the maximum force on first cycle, g); HPV, hot paste viscosity (the minimum hot paste viscosity); LSD, least significance difference; MLR, multiple linear regression; PLS, partial least square regression; PT, peak time; PV, peak viscosity (the maximum hot paste viscosity); Q^2, cross-validation correlation coefficient; R^2, multiple correlation coefficient; SB, setback (final viscosity minus hot paste viscosity); SV, swelling volume; T_c, completion temperatures (°C); T_o, onset temperature (°C); TP, time to peak; T_p, peak temperature (°C); WP, width at peak; W8, width after 8 min; ΔH, change in enthalpy (J g^{-1})

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Oil uptake into oil fried products can be explained by capillary action (Pinthus and Saguy, 1994) or by oil replacement of removed water (Gamble et al., 1987). During noodle frying, many tiny holes are created as water is rapidly removed and replaced by oil on the surface of the noodles (Hou, 2001). Generally, the content and quality of the wheat protein is believed to play a role in oil absorption. In a qualitative study, Moss et al. (1987) reported that noodles made from high-protein wheat flour absorbed less oil than noodles made from low-protein flour. They proposed that the high oil absorption in low-protein flour noodle was due to the formation of coarse globules during steaming, allowing oil to penetrate easily through the noodle (Moss et al., 1987). A significant inverse correlation between oil uptake and protein content has also been reported (Azudin, 1998; Park and Baik, 2004a). However, protein content is not the sole factor influencing oil uptake (Moss et al., 1987). Protein quality also significantly affects free oil absorption in instant noodles (Park and Baik, 2004a). Wheat flours with high-protein content and high SDS sedimentation volume or low proportion of salt-soluble protein may produce instant noodles with low levels of free lipids (Park and Baik, 2004a). A strong inverse correlation between amylose content and oil content of instant noodles was also reported using reconstituted flours (Park and Baik, 2004b). The influence of other wheat flour components, especially protein and starch quality, on oil content of instant noodles has not been fully explored.

Deep-fried instant noodles are widely preferred by consumers due to their excellent flavour, convenience and ease of preparation (Wu et al., 1998). However, like other deep-fried products, the high residual oil content, the presence of oil-derived compounds in deep-fried products, and their potential health impact has raised concerns (Saguy and Dana, 2003). Excessive lipid consumption is correlated with obesity, cardiovascular disease and other health disorders, and pressure from governmental and consumer groups to restrict the level of lipids in foods has increased (Roberts, 1989). The high oil uptake by noodles during frying also increases production costs and adversely affects shelf-life (Moss et al., 1987; Rho et al., 1986). Besides, the high oil content is often not necessary for product quality (Goel et al., 1999).

A correlation study was conducted between wheat flour characteristics (chemical composition, protein and starch quality) and oil content of instant noodles to better understand the underlying component(s) or properties responsible for oil absorption during noodle making, as a guide to selection of appropriate wheat varieties, or in the development of strategies for oil control in instant noodle making.

2. Experimental

2.1. Materials

Wheat landraces with varied protein content and starch properties were selected to add diversity to the observed properties based on earlier studies (Bhattacharya and Corke, 1996; Bhattacharya et al., 1997). Five hexaploid wheat landraces originating from Iran were provided by Prof. C.O. Qualset of the University of California, Davis (Table 1). Four United States cultivars, Anza, Yolo, Yecora Rojo and Serra were produced under uniform field conditions at the University of California, Davis. A CES (Canadian Extra Strong) sample was supplied by the Canadian Grain Commission (Winnipeg, Canada). Seven commercial wheat flours consisting of Sandow, Red Bicycle, American Roses, Gloden Wheel, and "D" brand were purchased in Hong Kong while Wuxi and Huaian wheat flours were purchased from mainland China.

Wheat seeds were tempered to 15% moisture for 24 h and then milled to 70–72% extraction rate with a Quadrumat Junior flour mill (Brabender OHG, Duisberg, Germany), fitted with a sieving screen covered with 6XX (233 micron) silk mesh. Wheat starch was isolated from wheat flours according to the procedures described by Konik et al. (1993) and AACC (2000) Approved Method 38–10. The yield of starch from each flour sample was approximately 50–65%.

2.2. General analysis

Moisture, total ash, protein ($N \times 5.7$), total starch, damaged starch, and free lipids of wheat flour were measured by AACC (2000) methods 44-15A, 08-01, 46-11A, 76-13 (Total Starch Kit, Megazyme, Bray, Ireland), 76–31 (Starch Damage Kit, Megazyme, Bray, Ireland) and 30–25 (Soxtec System HT6, Tecator, Hogänäs, Sweden), respectively. Amylose content was determined using the Megazyme Amylose–Amylopectin Assay Kit as described by Yun and Matheson (1990). SDS sedimentation was performed according to Dick and Quick (1983) with 1 g wheat flour (as-is moisture basis) in a custom-made rack fitted with a measuring scale (0–112 mm) to read the SDS-sedimentation value (provided by the University of California, Davis). All measurements were performed in triplicate.

2.3. Mixograph tests

The dough water absorption and flour mixing characteristics were performed according to the approved AACC (2000) Method 54-40A using a 2-g mixograph with the Mixsmart programme for data acquisition and analysis (National Manufacturing Co., Lincoln, NE). The mixing parameters, time to peak (TP), width at peak (WP), width after 8 min (W8) and integral area beneath the mid-line from time zero to the peak time (PT), which was referred to as the work input for dough development, were automatically interpreted by the data processing software supplied with the instrument. Each test was conducted in triplicate.

2.4. Swelling volume (SV)

Starch SV was determined according to the method of Crosbie et al. (1992). Wheat starch (0.35 g, dwb.), was