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Feature of air classification product in wheat milling: Physicochemical, rheological properties of filter flour

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ABSTRACT

Wheat filter flours are by-products obtained from air-classification of wheat flour. Physicochemical and rheological properties of wheat filter flours were investigated in the present study. Average values of crude protein, gluten, lipid and damaged starch content of filter flours were higher than those of standard flours for the same batch. The positive correlation of particles with size <20 μm and damaged starch was found. Moreover, the filter flours had higher water absorption, stability time except head milling filter flour samples. Short peak time and low peak viscosity were also observed. Different composition of wheat filter flours may be an important factor influencing its properties. This study is very useful for exploring the utilization of wheat filter flours in the food industry.

1. Introduction

In the modern wheat milling industry, pneumatic conveying is widely used to transport the materials. When wheat flour passes through the air separation devices as centrifugal discharge or cyclone dust collector, etc., the heavy endosperm particles sink due to the effect of centrifugal force, the fine fractions spiral upwards with the airflow and eventually are collected by filter bag. The collection is called customarily wheat filter flour in England or suction stock in USA. As a by-product of the wheat milling, although the output of the filter flour is only 0.5%–1.5% of the processed wheat, it is a problem puzzling wheat flour millers. Returning filter flours to the machine and mixing them to common flour would result in increase in flour ash content, decrease in flour whiteness and poor dough proofing. Moreover, this processing easily plugs the mill equipment and impacts normal production of the flour mill (Wang and Gao, 2005). Now, many attempts are made to reduce the filter flour in wheat milling. The production of wheat filter flours is inevitable due to the presence of pneumatic conveying in wheat milling.

Because its formation is affected by airflow and gravity, wheat filter flour can be regarded as a specific product of air classification or dry fractionation. In fact, dry fractionation for the production of protein concentrates is applied to pulses (e.g., lentil, pea, and bean) and some cereals such as wheat and barley most successfully. Due to its specific tissue architecture and milling behavior, wheat flour was separated into fine and coarse fractions by air classification. The fine fraction was a protein-rich fraction (Schutyser and Goot, 2011). It could be explained by the average particle size and apparent density of wheat protein which is small (protein is 7 μm and 0.63 kg/l; starch is 20 μm and 0.90 kg/l) (Dijkink et al., 2007). Also, scanning electron microscopic pictures show small protein particles adhere to large smooth starch granules, and then they are blown apart by airflow. Létang and Samson (2001) reported the production of starch with low protein content flours by jet milling and air classification. Jones et al. (1959) separated the flours with different protein contents by air classification. However, in these studies, there is no information on whether protein-rich fractions produced by air classification come from the same part of the grain and whether these proteins have the same characteristics. In the past, researchers took it for granted that all proteins were extracted from wheat endosperm. But it is not appropriate for filter flours. There is a significant difference among the tensile properties of wheat filter flours from different mills, even for the samples with similar protein content. At the same time, the color of the flours is varied. In the present study, numerous samples of the filter flour from different mills were collected and analyzed in order to summarize their general character and differences.

Aside from protein fractions, the contents of other components (including some special nutritional ingredients) were also

Alphabetical list: S01-S07, standard flour; F01-F07, filter flour; FQN, farinograph quality number; RVA, Rapid Visco Analyzer; WA, Water absorption; BU, Brabender units; DDT, dough development time; MTI, mixing tolerance index.

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influenced by the air classifier. By grain micronization and air classification of barley flour, the content of β-glucan was enriched to 15.6% from 7.8% of materials (Ferrari and Finocchiaro, 2009). Moreover, the coarse fractions obtained by this process showed more than 57% of free flavan-3-ols and the content of bound phenolic compounds was higher than 60% compared to whole flour (Verardo and Ana Maria, 2011). Corn fiber was finely ground in a pin mill at high speed, and the resulting ground fiber was separated into various fractions with cut off points of 15, 18, 24 and 30 μm. The finest fraction, with a particle size of less than 15 μm, showed enriched protein, starch, fat and sterol ferulate contents compared with the starting corn fiber (Wu and Norton, 2001). For wheat flour, most of the studies focused on the effect of air classification on enrichment in protein fractions. Little information on changes in contents of other substances (ash, fat, damaged starch, etc.) was found although these substances greatly affected the rheological properties and end-food quality (Greffeuille and Lullien-Pellerin, 2007; Bonnand-Ducasse et al., 2010; Lazaridou and Duta, 2007).

The present study aimed to analyze the distributions and changes in moisture, ash, starch, damaged starch, protein, lipid, flour color and gluten of wheat filter flours collected from different millings. The properties of gluten and the rheological properties of wheat filter flours were investigated. Moreover, the relationships among these quality indicators have also been analyzed. In this experiment, some samples of wheat filter flour were intercepted successively in the break system, reduction system and scratch system (namely, the head, middle and tail of the wheat milling process), in order to explore the impact of a single system on the blended filter flour.

2. Material and methods

2.1. Flour and filter flour samples

The samples of wheat standard flour and filter flour of the same batch collected from ten different flour companies in Henan province of China were used in the present study. The samples of standard flour were named as S01-S07 in turn, and the filter flour samples were named as F01-F07, which was blended filter flour as mentioned before. Meanwhile, the other two samples of standard flours, JYS and MXS, and six filter flour samples from three systems (the head, middle and tail of the mill) were also used (JY01-03, MX01-03).

2.2. Physicochemical analysis

The contents of moisture, ash and crude lipid in flours were determined according to Chinese National Standard (GB5497-85, GB 5009.4-2010, GB5512-85). Nitrogen content was determined using the Kjeldahl method (AACC, 2000) and crude protein content was estimated as $N \times 5.7$. Before determining the starch content, the samples were firstly pretreated by 1% hydrochloric acid, and then the content of starch was determined using a model 341 polarimeter (PerkinElmer, Massachusetts, USA). Damaged starch content was evaluated by the AACC method 76-30A (AACC, 2000). Contents of gluten, whiteness and color were respectively determined by the MJ-IIB Gluten Testing System (Zhonglang, Sichuan, China) according to GB/T5506.2-2008, WGB-2000 Whiteness Meter (Huier, Hangzhou, China) and DC-P3A Color-difference Meter (Hengaode, Beijing, China). In the color difference analysis, ‘L*’ value indicates degree of lightness or darkness ($L^* = 0$ indicates perfect black and $L^* = 100$ indicates most perfect white); ‘a*’ indicates degree of redness (+) and greenness (−); whereas ‘b*’ indicates degree of yellowness (+) and blueness (−).

2.3. Measurement of sample particle size distribution

The particle size distribution of samples was determined by light-scattering using a Malvern Mastersizer X (Malvern Instruments Ltd., Worcestershire, UK) equipped with a 100-mm focal length lens. The active laser beam length was 14.3 mm. Particle size distributions were analyzed using Mastersizer-s (V 2.18) software. The Fraunhofer diffraction model, assuming a standardized spherical shape, was used to analyze all samples (Raeker et al., 1998). All particle size distributions were measured in triplicate.

2.4. Evaluation of dough quality properties

Farinograph water absorption, development and stability of dough prepared from the wheat filter flours were determined by a Farinograph equipped with a 50 g-stainless steel bowl (Brabender Farinograph) according to Approved method 54-21 of AACC. Resistance and extensibility of dough prepared from the substituted flours were also tested using a Brabender extensograph according to Approved method 54-10 of AACC.

2.5. Analysis of starch pasting properties

The pasting properties were determined using the Model 3D Rapid Visco Analyzer (RVA, Newport Scientific, Australia) according to the method proposed by Chang et al. (Chang et al., 2004). The flour suspension was treated by the following steps: equilibration at 50 °C for 1 min; heating to 95 °C at a rate of 12 °C min^{-1} and maintaining at 95 °C for 2.5 min; cooling to 50 °C at a rate of 12 °C min^{-1}, and maintaining at 50 °C for 1 min. Paddle speed was set at 960 rpm for the first 10 s and 160 rpm for the remaining time. The pasting parameters, peak time, pasting temperature, and peak (P), hold, final, breakdown, and setback viscosity parameters were determined *in situ* for the starch suspension.

2.6. Statistical analysis

The data reported in all the tables are averages of triplicate observations. Analysis of correlation was conducted using the SPSS 17.0. Two levels of significance were marked $p < 0.05$ and $p < 0.01$.

Table 1
Content of basic components of standard flours and filter flours (%).

Samples		Moisture	Ash	Lipid	Protein	Starch	Damaged starch	Particle size <20 μm
I	S01	15.03	0.69	0.93	13.11	67.35	9.92	8.72
	S02	13.96	0.64	1.02	14.76	68.16	13.2	13.1
	S03	14.83	0.47	0.81	11.3	71.92	11.48	7.25
	S04	14.64	0.51	0.68	10.57	72.21	12.96	9.04
	S05	13.82	0.69	0.75	12.19	69.13	13.61	11.49
	S06	14.36	0.65	0.85	11.18	69.91	13.12	9.95
	S07	14.84	0.5	0.73	12.71	71.29	9.85	7.31
	JYS	11.07	0.48	0.96	13.1	69.8	7.08	5.82
	MXS	13.91	0.55	0.91	12.88	70.05	7.78	8.21
II	F01	10.25	0.91	1.78	20.18	62.91	12.38	32.02
	F02	11.99	0.82	1.56	16.09	67.52	15.99	32.13
	F03	10.66	0.85	1.97	19.42	62.19	13.37	31.35
	F04	10.26	1.08	2.08	20.65	59.86	14.92	36.08
	F05	10.85	1.11	2.12	17.46	63.97	16.24	33.86
	F06	10.36	1.17	2.34	20.01	56.61	15.42	36.56
	F07	10.14	0.59	1.25	22.56	60.48	11.32	34.81
III	JY01	10.83	0.48	1.03	15.29	67.31	10.41	19.6
	JY02	10.24	0.49	1.45	24.46	57.56	9.68	35.04
	JY03	9.78	0.88	2.45	23.51	55.93	13.37	40.19
	MX01	11.28	0.56	1.19	19.7	63.4	8.45	18.65
	MX02	10.55	0.57	1.5	23.87	58.4	11.07	37.06
	MX03	10.06	1.13	2.57	26.51	52.8	13.37	43.27

The samples in I column were standard flours, II column samples were blended filter flours, and III column samples were filter flours.