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Research Article

Relationship of Moisture Status and Quality Characteristics of Fresh Wet Noodles Prepared from Different Grade Wheat Flours from Flour Milling Streams

Li Li,[1,2] Na Wang,[2] Sen Ma ,[1,2] Songzhu Yang,[2] Xuehua Chen,[2] Yingying Ke,[2] and Xiaoxi Wang [2]

[1]*Province Key Laboratory of Transformation and Utilization of Cereal Resource, Henan University of Technology, Zhengzhou, Henan 450001, China*
[2]*College of Grain and Food Science, Henan University of Technology, Zhengzhou, Henan 450001, China*

Correspondence should be addressed to Sen Ma; masen@haut.edu.cn and Xiaoxi Wang; xxwanghaut@126.com

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This study was performed to investigate the quality of fresh wet noodles made from flour milling streams. The basic composition, texture properties, cooking characteristics, and moisture status were measured to evaluate the qualities of noodles. The results indicated that as storage time increased, the springiness of fresh wet noodles gradually decreased, but the hardness increased. Additionally, the cooking loss rate was increased obviously, and the water absorption rate generally decreased. The relaxation times T_{21} and T_{22}, analyzed by low-field nuclear magnetic resonance, showed a downward trend that proton mobility became poor and bound water changed into intermediate water. Noodles made from reduction flour exhibited better quality. Compared to that with ambient temperature storage, the wet noodles under frozen storage showed better quality. The relaxation time T_{21}, and T_{22} showed a positive correlation with noodle quality.

1. Introduction

Free water, intermediate water, and bound water are three forms of water in food [1]. As an important component of many foods, water has a decisive influence on food's rheological characteristics and its chemical and physical properties [2, 3]. The presence, distribution, and concentration of water strongly influence the processing characteristics, stability, and preservation properties of food [4].

Low-field nuclear magnetic resonance (NMR) technology is an effective tool to study the water status of food, mainly by determination of the proton relaxation behavior [5, 6]. The relaxation process occurs through fluctuations in the magnetic field caused by random molecular motions, both rotational and translational. The rate and the characteristics of these motions both affect the decay of the NMR signal, which is observed by the T_1 and T_2 relaxation times [7]. The NMR signal is commonly analyzed in terms of two main parameters, T_1 and T_2. The spin-lattice (T_1) relaxation involves the transfer of energy between the spin system and the environment, and spin-spin relaxation (T_2) processes involve the dephasing of nuclear spins, which are entropic processes [8]. The T_2 can be used to analyze the interactions between water and dough. The T_2 value is sensitive to water distribution with different mobility states [9]. Two transverse relaxation time constants, T_{21} and T_{22}, are spin-spin relaxation time constants and were identified from the NMR experiments using the Carr–Purcell–Meiboom–Gill (CPMG) pulse sequence. The existence of these time constants indicates the presence of two distinct fractions of water. T_{21} is the portion of water that is strongly associated with other molecules by hydrogen bonding, almost "bound" water. However, T_{22} is more mobile water with a high molecular mobility. T_{21} and T_{22} have different relaxation rates and degrees of mobility. Generally, shorter T_{21} values indicate less mobile water, and longer T_{22} values indicate more mobile water [10].

A model of water distribution is useful to enable real-time monitoring and control of food quality during production and storage [11, 12]. Water mobility is mainly depended on the changes of hydrogen bonding structure. Hydrophilic materials such as proteins and carbohydrates can form hydrogen bonds with water molecules to influence the water mobility. Higher contents of proteins or carbohydrates decrease water mobility and vice versa [13].

Compared with dry noodles, wet noodles are fresher, with stronger boiling fastness, stronger gluten, better taste, and better flavor. However, the high moisture of fresh wet noodles can easily lead to spoilage, browning, rancidity, and deterioration, damaging appearance, quality, and flavor. At the same time, the change of both content and distribution of water during the milling of wheat flour contribute to the loss and migration of moisture and changes in flour characteristics. When noodles were stored at different temperatures (37°C, 45°C, or 55°C), T_{21}, T_{22}, and the content of free water increased, which indicated that migration and redistribution of water occurred [10]. Lai and Hwang found that the T_2 changed regularly with the moisture distribution and movement in noodles during cooking and storage. Additionally, the surface and the interior water showed different migration behaviors during storage, and moisture migration played a decisive role in the hardening of noodles [14]. Sekiyama et al. found that when the storage time was between 10 min and 120 min, the T_2 value on the surface of noodles decreased gradually with the extension of storage time, which was completely contradictory with the T_2 value of the center of noodles. This difference was mainly attributed to the redistribution of water. After 120 minutes, the water in different regions presented a certain moisture gradient, and the relaxation time T_2 was related to the microstructure and the degree of starch gelatinization of noodles [15].

The objectives of this research were to study the quality of fresh wet noodles made from different grade wheat flours of flour milling streams under different storage conditions, and the influence of storage temperature on the change of water status were observed by low-field NMR. Our finding was able to correlate water status and noodle quality, suggesting water status can be used to predict changes in noodle quality.

2. Materials and Methods

2.1. Materials. Wheat powders were obtained from the flour production workshop of Henan Zhonghe Co. Ltd. (Henan, China). Representative online wheat milling streams of break flour (2B, the number "2" represents the second time of milling, similarly hereinafter), reduction flour (1M, 2M, and 3M), and sizing flour (1S) were selected for the study. The basic physical and chemical indicators of the wheat milling streams are shown in Table 1.

2.2. Noodle Preparation. Fresh wet noodles were prepared as described previously [16]. Briefly, 100 parts of wheat flour and 35 parts of deionized water were mixed for 7 min using a pin mixer. The dough pieces were then hand kneaded into a stiff mass and passed through a laboratory noodle machine 4-5 times to form and compound a noodle sheet at a gap setting of 3.5 mm. The dough was then sheeted through five different roll gaps (3.0, 2.5, 2.0, 1.5, and 1.0 mm). Next, the sheet was cut into fresh noodle strands (15.0 cm length, 2.0 cm width, and 1.0 cm thickness) with cutting rollers.

2.3. Noodle Storage. Noodles were stored at room temperature (25°C) or in the cold (4°C) and were covered with a plastic wrap. Samples were then removed regularly and subjected to testing.

2.4. Chemical Analysis. Moisture and protein were measured following standard AACC methods (AACC, 2000). The starch content was determined by 1% hydrochloric acid polarimetry. Damaged starch (DS) content was determined using the SDmatic procedure [17]. The farinograph test was performed according to standard AACC methods (2000). The whiteness was determined according to GB/T 12097. The falling number was measured following GB/T10361-2008. D50 was determined using a laser particle size analyzer (BT-2002, Dandong BT Instrument Co. Ltd.). All analyses were performed in triplicate.

2.5. Texture Properties. The TA-XT2i type texture analyzer (Stable Micro Systems, UK) was used for texture property analysis (TPA), and a set of three strands of cooked noodles were placed parallel to each other on a flat metal plate. Hardness and springiness was determined. The experimental parameters were set as follows: pretest speed: 2 mm/s, test speed: 0.8 mm/s, posttest speed: 0.8 mm/s, minimum inductive force: 5 g, compression rate: 70%, and the time interval between two compression tests: 1 s.

2.6. Water Absorption. 20 g of noodles was cooked in 500 mL of boiling distilled water until the white core of the noodles disappeared, and a colander was used to separate the noodles from the water. The noodles were transferred to a filter paper, drained for 5 min at room temperature, and then weighed. The final results are the mean of triplicate determinations. The formula of water absorption index of dry matter was calculated according to the Chinese Standard Method GB 5497–1985.

2.7. Cooking Loss Ratio. Noodles and cooking water were cooled to room temperature and then transferred to a 500 mL volumetric flask and measured. Next, 50 mL of the above solution was poured into a 250 mL beaker of constant mass and then evaporated to dryness over a water bath. This evaporation procedure was performed as described above four times, drying a total 200 mL of the above solution. The dried material was then transferred to a hot air oven that was maintained at 105 ± 2°C and dried to constant mass. The cooking loss rate of dry matter (%) was calculated according to Zhang's method [18].

Table 1: The basic physical and chemical indicators of the wheat milling streams.

Sample	Moisture (%)	Protein (%)	Starch content (%)	Whiteness	D_{50} (μm)	Damaged starch (UCD)	Falling number (s)
1S	15.11	10.63	69.87	75.7	20.37	25.3	470
2B	15.11	12.69	66.85	68.5	23.76	19.0	423
1M	14.24	10.20	71.19	73.1	25.28	16.5	496
2M	13.52	10.43	70.66	71.9	25.92	15.6	508
3M	13.64	11.46	69.16	73.3	24.99	21.6	521

Note. S, sizing flour; B, break flour; M, reduction flour.

2.8. Nuclear Magnetic Resonance (NMR). NMR (NMR variable temperature analysis system, VTMR20-010V, Shanghai NM electronic Science & Technology Co., Ltd.) was used to assess the water properties of the noodles. The Carr–Purcell–Meiboom–Gill (CPMG) pulse sequence was used to determine the transverse relaxation time T_2 of samples. The test parameters were set as follows: number of echo (NECH) = 2000, number of scans (NS) = 16, and echo time (ET) = 0.1 ms. The NMR spectra and T_2 of samples were processed with T_2-FitFrm software.

2.9. Statistical Analysis. All the data obtained in the study were expressed as the mean of at least two determinations. Analysis of variance was performed, and the data were analyzed using Duncan's test (level of significance, $P < 0.05$) with SPSS software (SPSS Institute, Cary, NC, USA).

3. Results and Discussion

3.1. Textural Properties. As shown in Table 2, the hardness of fresh wet noodles showed an overall upward trend as the storage time was extended. When stored for the same length of time, the hardness of noodles stored at room temperature was greater than that of noodles subjected to cold storage. It was probably because the noodles stored under normal temperature were more likely to loss moisture, causing noodles to become relatively dry and hard [19]. Noodles made from 1M showed the largest hardness value, followed by 2M; the hardness of 1s was close to 3M, and noodles made from 2B showed the lowest hardness value. This was probably due to the variation of starch content in the noodle. Previous studies reported that starch content was positively related to hardness [20], and our experimental results are consistent with this finding, as shown in Table 1. The variation of protein content might also affect the hardness of the noodle. Flour with higher protein content had higher water holding capacity, preventing the moisture loss of the noodle during storage [21].

Table 3 shows that the springiness of fresh wet noodles decreased as storage time increased under different storage conditions. Additionally, the springiness of noodles stored at cold temperature was lower than for those stored at room temperature. This was probably caused by the further development of the gluten network at room temperature, but in the cold condition, this development process was more restricted [22]. The springiness of sizing and the reduction flour was greater than that of the break flour, due to the higher content of bran speck in break flour, which hindered the formation of the gluten network structure. The reduction and sizing flour properties were determined by the presence of the endosperm, evaluation of the flour quality, and more complete formation of the gluten network structure [23]. Li et al. studied the textural properties of noodles during storage and found that the hardness increased and the springiness decreased from 0 h to 24 h, and then the springiness decreased again at 36 h and 48 h, consistent with our results [24]. Other reports suggested that with the extension of storage time, the brittleness increased, and that had an effect on springiness. With storage time being increased, the alpha helix content in the gluten protein secondary structure decreased and random coil content increased, resulting in a decrease of springiness and cohesiveness in noodles [25, 26].

3.2. Cooking Properties. Table 4 shows that under different storage conditions, the cooking loss rate of all fresh wet noodles showed an obvious increasing trend with the extension of storage time. This change may be due to the starch retrogradation process and gluten network disruption during storage [27, 28]. This can lead to loosening of the starch and other small molecular compounds and the dissolution of small particles embedded in the gluten protein network, resulting in increased cooking loss rate. Noodles stored in the cold showed lower cooking loss rate than that stored at room temperature. As seen from Table 5, the water absorption rate of dry matter showed a downward trend during storage. The water absorption rate of dry matter was greater in the cold, which indicated the cold storage was helpful to maintain noodle quality. With increased storage time, the binding force between starch and the gluten network structure in fresh wet noodles weakened gradually. Subsequently, the dissolution of starch in the cooking process increased, leading to a gradual increase of cooking loss rate and a decrease of water absorption rate as storage time increased [16]. The water absorption rate of 1S presented the opposite trend under different storage temperatures. We speculated that, at higher temperature, there was more extensive contact between molecules, facilitating the formation of intermolecular chemical bonds. Moreover, the high content of damaged starch in 1S has great ability of combining with water. During cooking, the noodles showed a greater ability to swell, and the water absorption ability increased.

For the same amount of storage time, the largest cooking loss rate was exhibited for noodles made with 1M, followed by 3M noodles. Noodles made from 2B flour showed the smallest cooking loss rate, probably because in the reduction

Table 2: Hardness of fresh wet noodles made from different flours during storage.

Storage temperature	Flour variety	Storage time						
		0 h	1 h	3 h	6 h	12 h	24 h	48 h
25°C	1S	10763.5^{a}	10857.9^{ab}	11045.6^{abc}	10994.8^{abc}	11082.6^{bc}	11228.4^{c}	11286.2^{c}
	2B	9351.2^{a}	9466.1^{a}	9547.0^{a}	9993.8^{b}	10144.0^{bc}	10480.4^{c}	10508.8^{c}
	1M	13581.0^{a}	13915.9^{b}	14370.6^{c}	14881.0^{e}	14755.4^{e}	14708.3^{de}	14563.5^{d}
	2M	12105.5^{a}	12415.3^{b}	12526.7^{b}	12650.5^{bc}	12883.3^{c}	13322.6^{d}	13429.8^{d}
	3M	10354.7^{a}	10649.4^{ab}	10760.5^{bc}	10879.4^{bcd}	11032.9^{cde}	11160.8^{de}	11271.2^{e}
4°C	1S	10763.5^{bc}	10596.1^{b}	10621.0^{b}	10741.5^{bc}	10119.8^{a}	10765.8^{bc}	10848.0^{c}
	2B	9351.2^{a}	9386.0^{a}	9552.9^{ab}	9921.4^{c}	9834.9^{bc}	9916.4^{c}	10199.4^{d}
	1M	13581.0^{a}	13662.7^{a}	13715.3^{a}	13927.6^{b}	14024.8^{b}	13913.5^{b}	14366.8^{c}
	2M	12105.5^{a}	12222.6^{ab}	12299.4^{ab}	12597.1^{bc}	12608.8^{bc}	12897.0^{cd}	13028.7^{d}
	3M	10354.7^{a}	10467.5^{ab}	10510.6^{ab}	10652.8^{ab}	10845.3^{bc}	10819.6^{abc}	11205.6^{c}

Values for a particular column followed by different letters differ significantly ($P < 0.05$). S, sizing flour; B, break flour; M, reduction flour.

Table 3: Springiness of fresh wet noodles made from different flours during storage.

Storage temperature	Flour variety	Storage time						
		0 h	1 h	3 h	6 h	12 h	24 h	48 h
25°C	1S	0.638^{a}	0.639^{a}	0.633^{ab}	0.621^{ab}	0.589^{c}	0.609^{bc}	0.617^{ab}
	2B	0.605^{c}	0.604^{c}	0.581^{b}	0.576^{b}	0.567^{b}	0.575^{b}	0.552^{a}
	1M	0.641^{a}	0.634^{a}	0.607^{a}	0.611^{a}	0.598^{a}	0.623^{a}	0.608^{a}
	2M	0.635^{a}	0.647^{a}	0.653^{ab}	0.670^{b}	0.712^{c}	0.730^{c}	0.710^{c}
	3M	0.754^{a}	0.749^{a}	0.750^{a}	0.746^{a}	0.726^{a}	0.712^{a}	0.721^{a}
4°C	1S	0.638^{d}	0.632^{cd}	0.629^{cd}	0.646^{e}	0.615^{b}	0.624^{bc}	0.592^{a}
	2B	0.605^{c}	0.585^{bc}	0.575^{b}	0.550^{a}	0.537^{a}	0.539^{a}	0.550^{a}
	1M	0.641^{c}	0.611^{ab}	0.608^{ab}	0.615^{ab}	0.622^{bc}	0.612^{ab}	0.594^{a}
	2M	0.635^{a}	0.675^{bc}	0.666^{abc}	0.645^{ab}	0.696^{c}	0.662^{ab}	0.659^{ab}
	3M	0.754^{b}	0.743^{b}	0.753^{b}	0.754^{b}	0.732^{b}	0.708^{a}	0.704^{a}

Values for a particular column followed by different letters differ significantly ($P < 0.05$). S, sizing flour; B, break flour; M, reduction flour.

Table 4: Cooking loss rate of fresh wet noodles made from different flours during storage.

Storage temperature	Flour variety	Storage time						
		0 h	1 h	3 h	6 h	12 h	24 h	48 h
25°C	1S	4.14^{a}	4.23^{a}	4.38^{a}	4.58^{ab}	4.83^{bc}	5.10^{cd}	5.50^{d}
	2B	3.63^{a}	3.78^{b}	3.85^{bc}	3.91^{cd}	4.02^{de}	4.10^{e}	4.19^{f}
	1M	4.39^{a}	4.50^{a}	4.61^{a}	4.98^{b}	5.22^{c}	5.44^{c}	5.82^{d}
	2M	4.12^{a}	4.26^{a}	4.44^{a}	4.60^{a}	4.74^{a}	4.83^{a}	4.96^{b}
	3M	4.23^{a}	4.33^{a}	4.50^{b}	4.74^{c}	4.90^{d}	5.05^{d}	5.26^{e}
4°C	1S	4.14^{a}	4.19^{a}	4.36^{ab}	4.47^{ab}	4.66^{bc}	4.99^{cd}	5.13^{d}
	2B	3.63^{a}	3.68^{ab}	3.77^{abc}	3.84^{bcd}	3.91^{cde}	4.00^{de}	4.09^{e}
	1M	4.39^{a}	4.42^{a}	4.51^{ab}	4.63^{bc}	4.74^{cd}	4.85^{de}	5.00^{e}
	2M	4.12^{a}	4.22^{ab}	4.35^{bc}	4.46^{cd}	4.58^{de}	4.67^{e}	4.73^{e}
	3M	4.23^{a}	4.29^{a}	4.40^{b}	4.54^{c}	4.65^{d}	4.71^{d}	4.84^{e}

Values for a particular column followed by different letters differ significantly ($P < 0.05$). S, sizing flour; B, break flour; M, reduction flour.

flour, the protein colloidal particles failed to fully contact water molecules during dough kneading and fermentation due to the relatively limited amount of water. Therefore, the gluten network structure was unable to fully form in the reduction flour. Furthermore, the cooking loss rate was negatively correlated with protein content and wet gluten content. The higher the protein content, the lower the loss rate of cooking [29].

3.3. Water Properties. The relaxation time was positively correlated with the mobility of water molecules. The T_{21} expressed by the relaxation time of water was related to the presence of nonaqueous material, including gluten protein, starch, and other macromolecular substances, also known as "deep binding water" [30, 31]. The T_{22} represents the water associated with the starch/arabinoxylans, as the gelatinization process includes the absorption of water [32]. Figures 1(a) and 1(b) shows that, under different storage conditions, the relaxation time T_{21} of the bound-water of fresh wet noodles decreased as storage time increased. The T_{21} values of noodles stored at cold temperature were generally larger than those for noodles stored at room temperature, probably because the noodles stored at room

Table 5: Water absorption rate of fresh wet noodles made from different flours during storage.

Storage temperature	Flour variety	Storage time						
		0 h	1 h	3 h	6 h	12 h	24 h	48 h
25°C	1S	127.54^{e}	126.23^{e}	124.53^{de}	121.10^{d}	115.30^{c}	93.63^{b}	75.96^{a}
	2B	131.06^{e}	127.06^{de}	120.56^{de}	111.40^{cd}	101.37^{bc}	84.31^{b}	51.43^{a}
	1M	137.86^{d}	135.11^{d}	133.11^{d}	130.09^{d}	120.93^{c}	98.20^{b}	71.56^{a}
	2M	143.57^{g}	141.71^{f}	139.47^{e}	135.14^{d}	128.37^{c}	122.86^{b}	120.16^{a}
	3M	131.24^{e}	130.06^{de}	128.59^{de}	127.72^{d}	123.95^{c}	120.98^{b}	110.61^{a}
4°C	1S	127.54^{c}	123.12^{abc}	119.28^{a}	121.53^{ab}	124.81^{bc}	139.07^{d}	144.48^{e}
	2B	131.06^{d}	133.17^{d}	136.72^{e}	130.05^{d}	125.87^{c}	120.67^{b}	97.04^{a}
	1M	137.86^{b}	143.73^{c}	149.51^{d}	147.88^{d}	142.72^{c}	136.94^{b}	128.98^{a}
	2M	143.57^{cd}	146.70^{de}	148.95^{e}	146.10^{cde}	142.97^{bc}	139.67^{ab}	136.73^{a}
	3M	131.24^{c}	135.76^{d}	142.50^{f}	139.66^{e}	132.67^{c}	126.93^{b}	120.78^{a}

Values for a particular column followed by different letters differ significantly ($P < 0.05$). S, sizing flour; B, break flour; M, reduction flour.

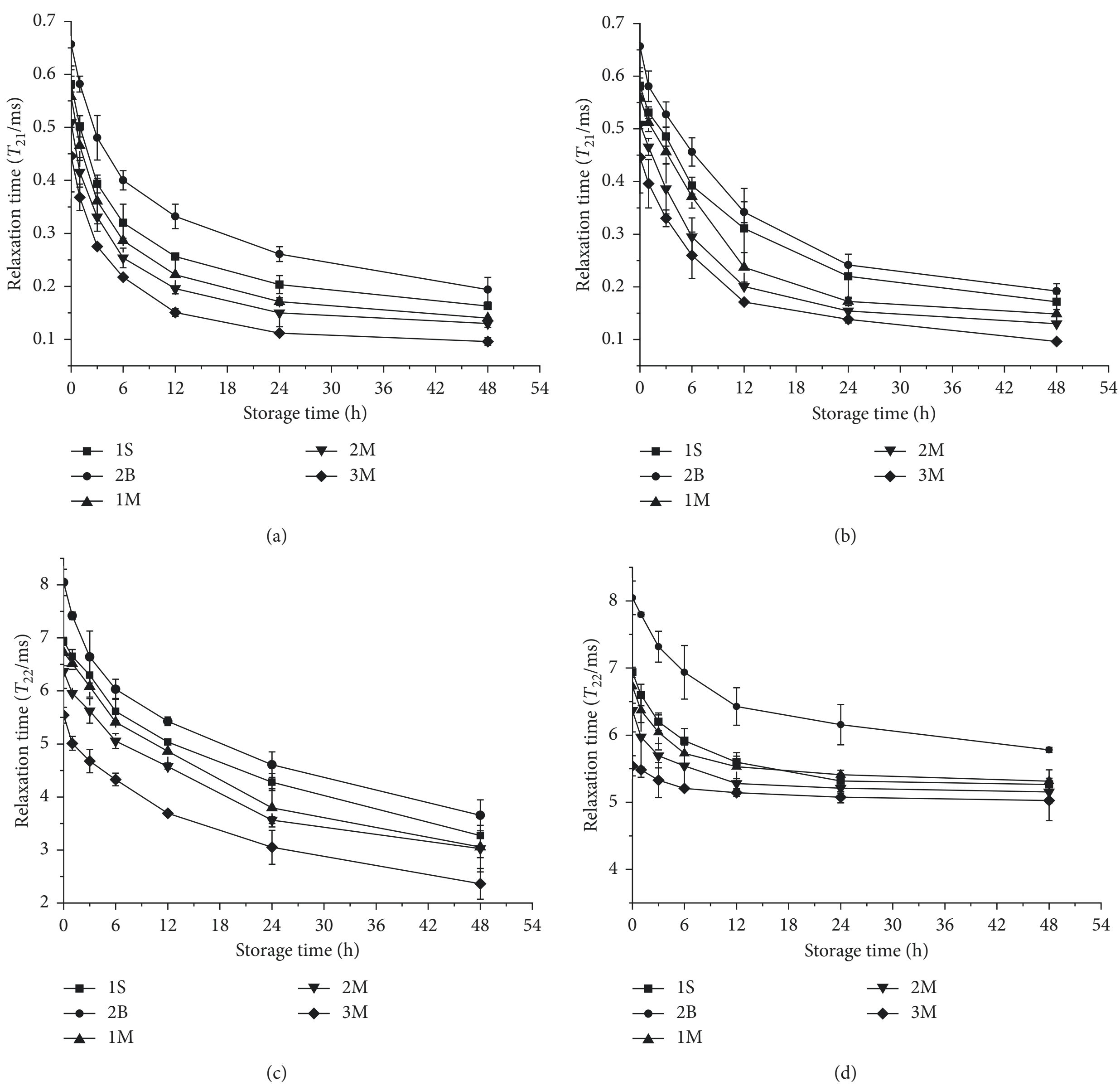

Figure 1: The water status of fresh wet noodles during storage. Relaxation time T_{21} at 25°C (a); T_{21} at 4°C (b); T_{22} at 25°C (c); T_{22} at 4°C (d).

Table 6: Correlation analysis between moisture and quality indicators of wheat flour.

Flour variety	Storage temperature	Water status	Hardness	Springiness	Water absorption rate	Cooking loss rate
1S	25°C	T_{21}	−0.964**	0.757*	0.826*	−0.939**
		T_{22}	−0.940**	0.646	0.957**	−0.999**
	4°C	T_{21}	−0.043	0.726	−0.760*	−0.988**
		T_{22}	0.050	0.657	−0.626	−0.953**
2B	25°C	T_{21}	−0.976**	0.942**	0.922**	−0.992**
		T_{22}	−0.971**	0.933*	0.961**	−0.991**
	4°C	T_{21}	−0.924**	0.902**	0.804*	−0.993**
		T_{22}	−0.950**	0.924**	0.787*	−0.995**
1M	25°C	T_{21}	−0.989**	0.724	0.806*	−0.947**
		T_{22}	−0.948**	0.506	0.954**	−0.993**
	4°C	T_{21}	−0.935**	0.557	0.536	−0.980**
		T_{22}	−0.899**	0.655	0.319	−0.938**
2M	25°C	T_{21}	−0.951**	−0.931*	0.946**	−0.993**
		T_{22}	−0.992**	−0.920**	0.991**	−0.969**
	4°C	T_{21}	−0.969**	−0.328	0.717	−0.996**
		T_{22}	−0.923**	−0.454	0.555	−0.979**
3M	25°C	T_{22}	−0.882**	0.877**	0.818*	−0.972**
		T_{22}	−0.704	0.902**	0.950**	−0.988**
	4°C	T_{21}	−0.905**	0.836*	0.584	−0.991**
		T_{22}	−0.889**	0.771*	0.498	−0.981**

*, **Correlation coefficient is significant at $P < 0.05$ and 0.01, respectively. S, sizing flour; B, break flour; M, reduction flour.

temperature suffered a greater loss of moisture content, the mobility of protons decreased, and there was diminished signal amplitude of the corresponding protons [33]. For the fresh wet noodles made from different flours, 2B showed the maximum relaxation time T_{21}, and 3M showed the minimum value. This difference was likely due to the high moisture content of 2B and the low moisture content of 3M.

Figures 1(c) and 1(d) show that, under different storage conditions, the extension of storage time for all fresh wet noodles gradually decreased the relaxation time T_{22} of the intermediate state water, and the water transformed from the combinative state to the intermediate state, for an overall decrease of total water content. Wang et al. also determined the water status in the noodle drying process using a low-field nuclear magnetic resonance analyzer, and reported that the weakly bonded water with transverse relaxation time T_{22} accounted for the largest proportion of water and the T_{22} value decreased gradually with drying time [34]. The relaxation time T_{22} was larger for noodles subjected to cold storage compared to noodles stored at room temperature. These differences are likely because of the higher moisture content, stronger proton mobility, and larger proton signal amplitude of the noodles stored in the cold. The largest relaxation time T_{22} was for 2B, and the 3M flour noodles showed the smallest value of T_{22}, in agreement with the observed relaxation time T_{21}.

The relaxation time T_2 reflects the number of water molecules with spin-spin relaxation time in the range of proton mobility. The decrease of relaxation time T_{22} and T_{21} is related to the migration and redistribution of water molecules in different states. For fresh wet noodles stored under different storage conditions, the hardness, acidity, and cooking loss rate increased with the decrease of the relaxation time T_{21} and T_{22}, and the whiteness, cohesiveness, springiness, and the water absorption of dry matter decreased. He et al. reported changes in the NMR parameters related to aging and moisture redistribution in steamed bread, and changes in moisture distribution were key to the aging process of steamed bread [35].

3.4. Correlation Analysis. The correlation analysis of quality characteristics and NMR parameters of fresh wet noodles made from different flours and stored under different storage conditions were determined and are shown in Table 6. The hardness values of all system powders were significantly negatively correlated with T_{21} and $T_{22.}$ Thus, the lower the water content (including both the bound water and the mobile water), the greater the hardness of noodles. The springiness showed positive correlation with both T_{21} and T_{22} values for 2B and 3M, with significant correlation. This result indicated that sufficient moisture content in noodles can help maintain the springiness of noodles. The cooking loss rate of all fresh wet noodles showed a highly significant negative correlation with T_{21} and T_{22}, and the correlation coefficients were above 0.9. Under room temperature storage, most water absorption rates for the powders showed a significant positive correlation with T_{21} and T_{22}. However, the correlations between the water absorption of dry matter and T_{21} and T_{22} were not significant during cold storage. Thus, under different storage conditions, the water status was significantly correlated with the quality of the flour in fresh wet noodles and the migration changes of different states of water affected the quality characteristics of noodles. Therefore, it may be feasible to predict changes in noodle quality through changes in the state of water.

4. Conclusions

Overall, the noodles made from 2B flour had lower whiteness, hardness, springiness, cooking loss rate, and water absorption rate of dry matter, compared with noodles made from reduction flour or sizing flour. With extended storage time, the relaxation time T_{21} and T_{22} decreased over 24 hours for all noodles. The relaxation time of noodles after storage at cold temperature was greater than that for noodles stored at room temperature. Noodles made from 2B flour showed the maximum relaxation time, and 3M noodles exhibited the minimum value. Clearly, the migration changes of different states of water influenced the quality characteristics of the noodles. In sum, 2M is the best type of flour for making wet noodles.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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