A Note on the Influence of High-Vacuum Drying on the Starch of Canadian Wheat Flours[1]

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ABSTRACT

A series of flours covering a wide range of flour types encountered in Canada were dried under high vacuum in a freeze-dryer. When water or aqueous reagents were added rapidly to the dried flours, it was observed that the damaged-starch content of these dried flours was invariably higher than that of normal "as-is" flours. If the dried flours were allowed to regain equilibrium moisture content slowly, the damaged-starch content of these "rehumidified" flours was similar to that of normal flours. It was concluded that the increase in damaged-starch content was caused by the rapid addition of water to dry flours, which resulted in stresses, set up partly as a result of high local heats of hydration around the flour particles at the moment of addition of water, and partly as a result of volume changes taking place in flour particles as a result of temperature fluctuation and resorption of water.

The laboratory freeze-dryer has of recent years become a popular and very useful tool, particularly in the fractionation of flours into suitable components for reconstitution studies. Although some loss of the activity of certain enzymes has been reported, the general impression is that changes which take place in the flour components as a result of this method of drying are minimal.

The purpose of this brief report is to draw the attention of cereal chemists to some alterations in the properties of starch which may take place upon subjecting flour to freeze-drying. Apparently, when water is added suddenly to a flour, the moisture content of which has been reduced to about 1%, sudden stresses are set up which result in a significant increase in starch damage as measured by a standard enzymological procedure. Experimental data are presented to illustrate this phenomenon which, if not recognized, may lead to misinterpretation of experimental results. The report of Whistler *et al.* (1) has established that various drying procedures may lead to cracking and fissuring of corn starch granules. The starch moiety of wheat flours, however, exists in a totally different environment, since it is more or less surrounded by lipoprotein and protein films, rather than in the naked state. The observations recorded here are confined to wheat starch in its natural state in flour. The observed increases in damaged starch in the range of flours studied are believed to have been caused by rapid addition of water to the dry flour. More gradual addition of moisture by slow humidification did not lead to the same results. Presumably the physical damage was caused by stresses similar to those described by Grosh and Milner (2) which arise in whole kernels of wheat as a result of tempering. The method of adding water to the flours described is not conducive to the making of microscopic studies, since the flour particles tend to agglomerate and lose their discrete particulate nature.

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MATERIALS AND METHODS

Flours milled from the common types of Canadian wheat were used in these experiments. A sufficient number of samples were examined to cover several factors normally encountered in the handling of wheat, namely, variations in protein content, low-temperature storage, and hot-air drying. The wheat samples used are described in Table I, together with information on flour protein content.

TABLE I
FLOURS USED IN STUDYING EFFECTS OF VACUUM-DRYING ON CONTENT OF DAMAGED STARCH

FLOUR No.	TYPE OF WHEAT	FLOUR PROTEIN (14% m.b.)	FLOUR No.	TYPE OF WHEAT	FLOUR PROTEIN (14% m.b.)
		%			%
1	Canada Eastern WW	7.4	11	No. 1 Man. Northern HRS (dried)[b]	14.7
2	Canada Eastern WW	7.5	12	No. 1 HRS (frozen)[c]	14.7
3	Canada Eastern WW	8.5	13	No. 2 HRS	10.8
4	Canada Eastern WW	9.7	14	No. 2 HRS	11.8
5	Canada Western WS	8.6	15	No. 2 HRS	12.6
6	Alberta RW	11.8	16	No. 2 HRS	13.5
7	No. 1 Man. Northern HRS	14.6	17	No. 2 HRS	14.6
8	No. 1 C.W. Garnet	11.3	18	No. 2 HRS	15.3
9	No. 2 C.W. amber durum (ADF)[a]	15.3	19	No. 3 HRS	16.0
10	No. 2 C.W. amber durum (ADS)[a]	15.0			

[a]No. 10 was milled to semolina from one-half of the original parcel of wheat.

[b]Moisture was raised to 16.8% by humidification, then dried to 12.9% by hot-air blast through a sieve containing the wheat (1 kg.).

[c]Moisture was raised to 15.5% by humidification, then wheat was frozen in trays for 16 hr. at –10°C. and a further 2 hr. at –40°C. Finally it was allowed to come to equilibrium at room temperature before conditioning and milling.

All flours and the semolina were milled from the original wheats on an Allis-Chalmers experimental mill. Damaged-starch content was determined by the method of Farrand (3). Protein content, diastatic activity, and gassing power were determined according to standard AACC procedures. Each flour or semolina was divided into two portions, one being retained as control, the other dried to about 1% moisture in the Stokes freeze-dryer and stored in screw-top jars pending analysis.

RESULTS

Effects of Vacuum-Drying on Damaged-Starch Content, Diastatic Activity, and Gassing Power of Flours from Wheats of Different Classes

A preliminary experiment showed that flours frozen for up to 4 days at –12°C. gave no indication of an increase in damaged-starch content in the absence of the vacuum-drying process, suggesting that the latter is solely responsible for the starch-damaging effects. Consequently, freezing of the flours before drying was considered unnecessary.

The levels of damaged starch likely to be encountered among the various classes of Canadian wheat flours are indicated by the data on normal flour in Table II. The soft white winter and white spring types were lowest in damaged starch, the hard red winter types rather higher, and normal hard red

TABLE II
DAMAGED-STARCH CONTENT OF "NORMAL" AND "VACUUM-DRIED" FLOURS FROM DIFFERENT TYPES OF WHEAT

FLOUR No.	WHEAT TYPE	NORMAL FLOUR		VACUUM-DRIED FLOUR	
		Moisture	D.S.[a]	Moisture	D.S.[a]
		%	%	%	%
1	WW	12.0	0.6	1.0	5.0
2	WW	13.9	1.8	1.5	6.0
3	WW	12.2	4.1	1.3	7.1
4	WW	12.3	2.7	1.5	5.2
5	WS	13.5	3.9	1.6	8.1
6	ARW	14.8	8.8	1.3	12.8
7	HRS	13.6	17.6	1.4	20.4
8	Garnet	14.7	28.4	1.4	33.2
9	ADF	14.5	42.3	1.0	46.7
10	ADS	13.7	14.6	1.9	17.6
11	HRS (dried)	13.5	13.1	1.5	17.6
12	HRS (frozen)	13.3	17.0	1.4	20.4
13	HRS	14.6	20.5	1.0	24.2
14	HRS	14.3	24.4	1.4	28.3
15	HRS	14.5	18.4	1.1	24.0
16	HRS	14.0	18.6	1.3	24.3
17	HRS	14.2	17.4	1.0	20.6
18	HRS	14.4	13.6	1.6	18.8
19	HRS	14.4	11.5	1.6	17.0

[a]These results are reported on 14.0% moisture basis.

spring was higher yet, at about 16–20% damaged starch. Garnet flours were still higher whereas the highest of all were durum flours at over 40% damaged starch. Durum semolina contained considerably less damaged starch than the flour, owing to the relatively less severe grinding required in its preparation.

Clearly, the vacuum-dried flours were significantly higher in damaged-starch content than the normal flours, with the highest relative increases in the soft wheat flours. For example, flour No. 2 (WW) increased from 1.80 to 6.02%, which represents more than a threefold increase over the original flour. Flour 9 (ADF), however, only increased from 42.25 to 46.66%, a relative increase of about 10% over the original material. Freezing the wheat prior to milling had no significant effect upon the damaged-starch content of the subsequent flour, but drying the wheat appeared to result in flours of lower damaged-starch content. This phenomenon is probably related to the minute surface cracks that have been reported to develop during drying of wheat (4), which may be expected to cause the grain to mill more easily. There was a tendency for the damaged-starch content of HRS wheat flours to diminish as protein content increased. A project now under investigation is expected to realize more comprehensive data on this aspect, however.

Table III indicates that the results obtained on damaged starch are not reflected quite so clearly in terms of either diastatic activity or gassing power.

It must be borne in mind, however, that other factors than damaged starch contribute toward both of these parameters—namely, enzyme systems and the inherent sugar content of the flours. In several instances diastatic activity showed a significant rise as a result of the drying process; but, in gen-

TABLE III

EFFECT OF VACUUM-DRYING ON FLOUR DIASTATIC ACTIVITY AND GASSING POWER

Flour No.	Wheat Type	Diastatic Activity[a]		Gassing Power[a]	
		Normal	Dried	Normal	Dried
		mg.	*mg.*	*mm. Hg at 6 hr.*	
1	WW	92	96	295	315
2	WW	87	91	252	262
3	WW	88	98	272	315
4	WW	87	84	274	267
5	WS	105	107	335	310
6	ARW	114	127	244	239
7	HRS	142	141	295	295
8	Garnet	224	225	384	371
9	ADF	294	322	485	488
10	ADS	146	138	333	328
11	HRS (dried)	141	144	300	276
12	HRS (frozen)	135	147	301	290
13	HRS	183	184	397	405
14	HRS	171	186	384	361
15	HRS	170	172	384	374
16	HRS	149	160	323	318
17	HRS	141	150	310	298
18	HRS	143	140	279	291
19	HRS	133	147	345	334

[a]These results are reported on 14.0% moisture basis.

eral, these results serve to point out that increasing damaged starch will not necessarily lead to an increase in either diastatic activity or gassing power. They also serve to illustrate that diastatic activity and gassing power in HRS wheat flours tend to fall as protein content rises, to an extent where the gassing power may be actually lower than that of much softer types.

Farinograph Studies on Water Absorption of Vacuum-Dried Flours

Damaged starch is known to exert a significant influence on the water absorption of flours (5). It was considered that the effects reported above should be confirmed by experimental determinations of flour-water absorption by means of the farinograph. At the outset of the farinograph study, temperature of dough of the dried flours was observed to increase significantly, particularly during the first 5 min. of mixing. Since temperature has been shown to affect dough consistency (6), three series of HRS wheat flours were studied in this experiment and are designated as "normal," "vacuum-dried," and "dried-rehumidified" flours, respectively. The last-mentioned series consisted of vacuum-dried flours which had been placed in a humidifying cabinet at 30°C. to regain moisture slowly (over about 24 hr.) to approximately the original moisture level.

Farinograms were obtained for all three series at the water absorption of the "normal" series, and are shown in Fig. 1.

Dough consistency rose significantly in the "vacuum-dried" series, but fell back in the "rehumidified" series to about the same level as that of the "normal" series in most of the flours that were examined. This was true notwithstanding the increase in temperature, which may have been expected to

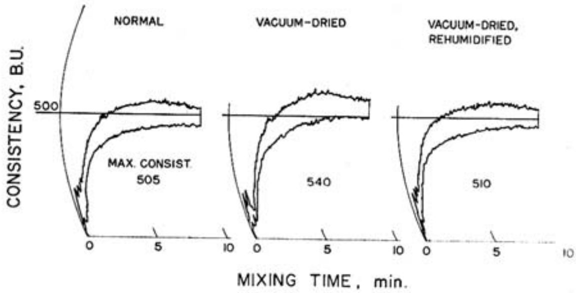

Fig. 1. Effect of vacuum-drying and subsequent rehumidifying on farinogram characteristics of a hard red spring wheat flour.

result in a decrease in consistency rather than in an increase (6). This rather unusual behavior resulted in a redetermination of the damaged-starch content of all three series of flours (Table IV), and it was found that the damaged-starch content of the third series which was rehumidified slowly was of the same order as that of the first series ("normal" flour), although that of the second series was significantly higher.

TABLE IV

DAMAGED-STARCH CONTENT[a] OF THREE FLOURS BEFORE DRYING, AFTER DRYING, AND AFTER REHUMIDIFICATION TO ORIGINAL MOISTURE CONTENT

Treatment	Damaged Starch		
	No. 20	No. 21	No. 22
	%	%	%
Normal (control)	12.6	16.2	16.7
Vacuum-dried	19.4	23.1	21.9
Vacuum-dried and rehumidified	14.0	15.9	14.9

[a]Results are reported on 14.0% moisture basis.

DISCUSSION

The increase in damaged starch observed in the dry flours and confirmed by the farinograph studies is believed to have been caused by the method of addition of aqueous reagents to the flours during determination of starch damage, or water in the case of the farinograph.

It has been reported previously that flours have an appreciable heat of hydration (7), and also that during remoistening of dry wheat a significant volume change takes place (8). It is believed that both of these factors contribute toward the phenomenon described which takes place during rapid addition of water or aqueous reagents to dry flours. Heat is probably developed locally on flour particles to a considerably higher degree than that reported; and it is this heat, in conjunction with volume changes that take place as a result of both temperature variation and resorption of moisture, which produces stresses on starch granules which in turn cause minute local ruptures and fissures. If the dry flours are allowed to imbibe water more slowly, these stresses do not occur to the same extent, and the starch damage of such rehumidified flours will not be appreciably different from that of normal undried flours. Cereal technologists concerned with any studies involving vacuum-drying of flour should be aware that careful rehumidification is necessary to avoid introduction of the effects of damaged starch and water absorption described above.

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