Sieving Characteristics of Soft and Hard Wheat Flours[1]

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ABSTRACT

The influence of four flowability characteristics on sifting efficiency was studied. Each flour system was sifted over a U.S. Standard 120-wire sieve through the use of a Rotap sifter. The amount of material passing through the sieve as a function of time was collected, and the results were plotted on log-log paper. The data produced a straight line. The slope of the line was the sieving index, and the y intercept was the fraction passing at unit time. Those two variables (sieving index and y intercept) were used to ascertain the influence of moisture content, presence or absence of fat, particle size distribution, and particle surface roughness on sifting efficiency. Hard and soft wheat flour did not have the same sieving indexes until moisture content, presence or absence of fat, particle size distribution, and particle surface roughness were held at equivalent values. The sieving index for hard and soft wheat flour was controlled by the cohesiveness of the flour system.

Sieving is the simplest method of interparticle separation. It is a process involving dry separation of particles based on size. Although the sieving process has changed little since its inception, few attempts have been made to explain the laws that govern it. The first successful scientific explanation of the mechanics of sieving was made by Whitby (1958), who used a standard Tyler Rotap sieve shaker to investigate sieving. The principal information available in a nonsteady-state approach to sieving, such as the Rotap, is the amount of material passing through the sieve as a function of time. Whitby's preliminary experiments, in which the standard Tyler Rotap and U.S. standard sieves were used, showed that plotting the percentage of particles passing through a sieve versus sieving time gave a curve that could be divided into two distinct regions (Fig. 1). The first region is during the early portion of sieving when there are still many particles on the sieve that can pass the mesh size. Region 2 begins when the residue on the sieve consists entirely of near-mesh or larger particles. Whitby (1958) further discovered that, if the data for region 1 were plotted on log-log paper, a straight line was produced. The straight line would obey the relationship $P = at^b$, where P = percent flour passing through the sieve, a = fraction passing at unit time, b = rate at which material passed the sieve or sieving index, and t = sieving time.

The only other area of sieving that has received attention in the literature is sieve blinding. Sieve blinding is when particles block up and lodge in the sieving mesh (Beddow 1981). The process of blinding in batch sieving occurs in four distinct stages (Nichols et al 1969). The last stage of blinding, which is the most detrimental to sieving efficiency, is referred to as hard blinding. The extent of hard blinding is strongly affected by both particle size and shape (Roberts and Beddow 1968).

Using an Instron test developed by Baruch (1974), we studied the flowability of hard and soft wheat flours (Neel and Hoseney 1984). We reported that the bridging threshold and bulking number of a flour system was dependent on three basic factors found in both hard and soft wheat flours and on one factor found only in soft wheat flour. Moisture content, presence or absence of fat, and particle size distribution all have the same effect on hard and soft wheat flour flowability. Soft wheat flour also has a rough particle surface, which causes it to flow less freely than hard wheat flour. The purpose of this investigation was to study the effect of those four characteristics on sifting efficiency.

MATERIALS AND METHODS

The flours used were described previously (Neel and Hoseney 1984). The CEM Corporation AVC model MP microwave-oven method was used to determine flour moistures (Davis and Lai 1984). Particle size analysis, flour particle size reduction, and flour defatting were as described previously (Neel and Hoseney 1984).

The standard Rotap sieve shaker and U.S. standard sieves made by the W. S. Tyler Company were used for sieving tests. The 8-in. full-height U.S. standard sieves (120-wire) were new at the beginning of this study. A controlled-humidity room was used for the entire study. The relative humidity was kept at 58% by using both a humidifier and a dehumidifier. The relative humidity was automatically monitored and controlled by a system built by Honeywell. It was double-checked periodically by use of a sling-type psychrometer. A 200-g sample was used for all sieving tests. The Rotap was operated through a clock and set to operate at intervals of 5 and 10 sec. The amount of material passing through the 120-wire sieve and into the pan was weighed at each time interval. The amount of flour passing through the sieve was converted into a percentage of the initial 200-g sample. These data were plotted against time on log-log paper. The data yielded a straight line with the equation $P = at^b$, where P = percent of flour passing through the sieve and t = time. The y intercept was a, the fraction passing at unit time. The slope of the line, b, was the rate at which the flour was passing through the sieve or sieving index. Those two basic parameters (a and b) were used to study the different sieving characteristics of the particulates.

RESULTS AND DISCUSSION

The procedure of Whitby (1958) was used to show the sieving differences between hard and soft wheat flours (Table I). The fractions passing at unit time (a) were 1.8 g and 1.2 g for hard and soft wheat flour, respectively. The sieving indexes were 1.07 and 0.50 for hard and soft wheat flour, respectively. The hard wheat flour was sieving at twice the rate of soft wheat flour. These data were evidence of the loss in throughput expected commercially when sieving soft wheat flour.

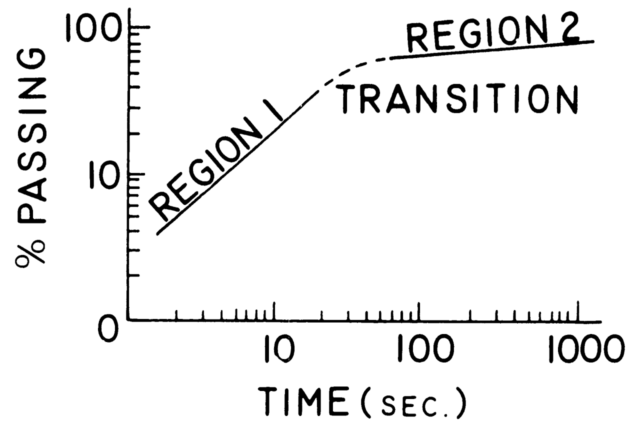

Fig. 1. Percentage of particles passing through a sieve versus sieving time.

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Presence or Absence of Fat

Defatted samples of hard and soft wheat flour were sieved on a Rotap sifter and the percent through by time was determined (Table II). The fractions passing at unit time (a) were 2.0 and 1.8 g for defatted hard and soft wheat flour, respectively. The sieving indexes or the rates at which the different defatted flours passed through the sieve were 1.80 and 1.30 for defatted hard and soft wheat flour, respectively. Defatting increased the sieving indexes of both hard and soft wheat flour. The sieving index of hard wheat flour increased from 1.07 before defatting to 1.8 after defatting. The sieving index of soft wheat flour increased from 0.50 before defatting to 1.3 after defatting. Although hard wheat flour sieved at twice the rate of soft wheat flour (1.07 versus 0.50) before defatting, it sieved only about one-third faster after defatting. The initial rates of sieving (a) for both samples were similar (2.0 versus 1.8).

The decrease in the difference between the sieving indexes of hard and soft wheat flour when defatted indicated that this difference is partially controlled by the more pronounced effect of fat on soft wheat flour. The bulking number and bridging threshold tests for regular and defatted soft wheat flour indicated that soft wheat flour was more cohesive than its hard wheat flour counterpart (Neel and Hoseney 1984). Defatting removed some of the natural cohesiveness of the flour systems. However, soft wheat flour must contain other attributes that enhance its cohesiveness and subsequently reduce its sieving index.

Particle Size Distribution

To study the effect of particle size distribution on sieving characteristics, a soft wheat flour with a hard wheat flour particle size distribution was produced by using the milling system discussed previously (Neel and Hoseney 1984). The bridging threshold and bulking number data for this sample indicated that its sieving characteristics should be between those of hard and soft wheat flour. The sieving results are shown in Table III. The sieving indexes (b) for hard wheat flour, soft wheat flour, and soft wheat flour with a hard wheat particle size distribution were 1.07, 0.50, and 0.87, respectively. The soft wheat flour sieving index was increased when the median flour particle size was increased (from 0.50 to 0.87). The bridging threshold and bulking number data indicated that soft wheat flour with a hard wheat flour particle size distribution was less cohesive than soft wheat flour and more cohesive than hard wheat flour.

The cohesiveness of a flour system must be involved in the sieving index. Particle size distribution has an indirect effect on sieving index. The change in median particle size distribution affects the cohesiveness of the flour system which, in turn, dictates the sieving index. In soft wheat flour, an increase in median particle size will increase the sieving index because the cohesiveness of the flour system is reduced. A decrease in median particle size would increase the cohesiveness of a flour system and, therefore, decrease the sieving index. The bulking number and bridging threshold data for hard wheat flour (Neel and Hoseney 1984) indicated that a reduction in median particle size would increase the cohesiveness of the flour system. An increase in hard wheat flour cohesiveness would decrease its sieving index.

To further investigate the effect of particle size distribution on sieving index, defatted hard and soft wheat flour samples with various median particle sizes were produced. The flour moisture content was that value obtained after each sample was defatted (7.0%). The three defatted hard wheat flour samples had median particle sizes of 73, 42, and 22 μm. The defatted soft wheat flour samples had median particle sizes of 71, 45, and 20 μm.

Defatted Hard Wheat Flour Results

The time-weight sieving data for the defatted hard wheat flours with various median particle sizes are shown in Table IV. A reduction in median flour particle size from the original hard wheat flour level (73 μm) to the level of flour pin-milled at 7,000 rpm (42 μm) produced an increase in the sieving index (from 2.46 to 3.15). A further reduction in median flour particle size to the level of the flour pin-milled twice at 14,000 rpm (22 μm) produced a decrease in the sieving index (from 3.51 to 1.40). A possible explanation for these results must take into account the three basic sources of interparticle forces in the different flour systems.

These interparticle forces will dictate the cohesiveness of the flour systems. The three basic types of interparticle forces are liquid bridges, molecular attraction, and frictional and mechanical forces

TABLE I
Percent Flour Passing Through U.S. Standard 120-Wire Sieve Versus Time (58% rh)

	Hard Wheat		Soft Wheat	
Time (sec)	Percent Through Sieve	Standard Deviation	Percent Through Sieve	Standard Deviation
5	7.3	1.8	4.1	0.77
10	13.0	3.8	73	1.4
20	24.5	6.0	12.5	2.4
30	34.3	8.1	17.2	3.6
40	44.8	10.9	21.8	9.3
50	53.3	12.7	26.2	5.0
60	61.3	13.8	30.0	5.7
70	67.5	14.4	33.9	6.2
100	70.5	14.3	39.9	7.3

TABLE II
Percent Flour Passing Through U.S. Standard 120-Wire Sieve Versus Time (58% rh)

	Defatted Hard Wheat		Defatted Soft Wheat	
Time (sec)	Percent Through Sieve	Standard Deviation	Percent Through Sieve	Standard Deviation
5	9.9	0.4	6.9	0.2
10	20.5	1.0	14.0	0.4
20	41.4	0.7	27.2	0.8
30	58.7	1.3	40.0	1.6
40	72.9	1.4	51.1	2.7
50	82.9	0.7	62.2	3.6
60	88.9	0.8	71.3	3.6
70	92.3	0.5	78.4	3.5
100	96.2	0.6	88.0	1.2

TABLE III
Percent Flour Passing Through U.S. Standard 120-Wire Sieve Versus Time for Soft Wheat Flour with a Hard Wheat Flour Particle Size Distribution (58% rh)

Time (sec)	Percent Through Sieve	Standard Deviation
5	6.1	0.8
10	11.8	0.1
20	21.1	1.4
30	36.7	1.2
40	44.9	1.0
50	52.0	1.2
60	59.0	1.8
70	72.8	1.8
100	80.7	1.6

TABLE IV
Sieving Rates (b) for Defatted Hard Soft Wheat Flours at Similar Median Particle Sizes

	Median Particle Size	Sieving at Unit Time (a)	Sieving Rate (b)
Defatted hard wheat flour	22	2.1	1.40
	42	4.2	3.15
	73	3.2	2.46
Defatted soft wheat flour	20	2.15	1.45
	45	3.2	2.34
	71	2.3	1.91

(Pilpel 1969). The possibility that liquid bridging was a factor was eliminated when the flours were defatted and sieved at a low moisture content (7%). Molecular attraction and frictional and mechanical forces are weak and dependent on the particle size (Pilpel 1969). The reduction in flour particle size from 73 to 42 μm merely produced additional flour particles that could pass through the sieve openings. The reduction in flour size was not great enough to increase the cohesiveness of the flour system to a point where the sieving index was affected. When the defatted hard wheat flour median particle size was reduced to 22 μm, the magnitude of the interparticle forces was increased to a level where the sieving index was decreased. The 22-μm defatted hard wheat flour was more cohesive than the other defatted hard wheat flours (42 and 73 μm) and therefore had a lower sieving index.

Defatted Soft Wheat Flour Results

The time-weight sieving data for the three defatted soft wheat flours with various median particle sizes are given in Table IV. A reduction in median particle size from the soft wheat flour with a hard wheat flour particle size distribution (71 μm) level to the original level of soft wheat flour (45 μm) produced an increase in the sieving index (from 1.91 to 2.34). A further reduction in median flour particle size to the level of the flour pin-milled twice at 14,000 rpm (20 μm) produced a decrease in the sieving index (from 2.34 to 1.45). This is the same type of relationship that was obtained with defatted hard wheat flour of various median particle sizes, and the explanation is the same. The interparticle forces were greater for the soft wheat flour pin-milled twice at 14,000 rpm. Those increased forces gave the defatted flour greater cohesion, which, in turn, reduced the sieving index.

Flour Particle Surface Texture or Roughness

To study the influence of flour particle surface texture or roughness on sieving index, all other flour particle attributes known to contribute to the cohesiveness of a flour system must be controlled. Other factors known to affect flour cohesion are moisture content, presence of fat, and particle size distribution. A series of defatted hard and soft wheat flours with very similar particle size distributions were produced (Table IV). The flour moisture content was that value obtained after each sample was defatted (7.0%). The soft wheat flour was pin-milled twice at 14,000 rpm. The median particle size achieved (20 μm) would reduce or eliminate flour particle surface characteristics as an influence on the cohesiveness of the flour system. Soft wheat flour particles would no longer exist as starch-protein aggregates with several starch granules protruding from the surface because a 20-μm median particle size is smaller than the size of a large starch granule. Individual particles at the 20-μm median particle size would consist of broken or whole starch granules or bits of protein material.

The sieving indexes (b) for the defatted hard and soft wheat flours at similar median particle sizes are listed in Table IV. Defatted hard and soft wheat flour with a median particle size of 73 and 71 μm had sieving indexes of 2.46 and 1.9, respectively. Defatted hard and soft wheat flour with a median particle size of 42 and 45 μm had sieving indexes of 3.15 and 2.34, respectively. Defatted hard and soft wheat flour with a median particle size of 22 and 20 μm had sieving indexes of 1.40 and 1.45, respectively. The key aspect of these results is that defatted soft wheat flour had a lower sieving index than defatted hard wheat flour for both the median particle sizes (45 and 71 μm) where soft wheat flour surface texture or roughness was maintained (2.46 versus 1.91, and 3.15 versus 2.34). Once the factor of surface roughness of defatted soft wheat flour was removed, defatted soft wheat's sieving index was practically identical to that of defatted hard wheat flour (1.40 versus 1.45). The bridging threshold values for these samples (Neel and Hoseney 1984) indicated that the defatted soft wheat flour was more cohesive than the defatted hard wheat flour for the 45- and 71μm median particle size distributions. When the median particle sizes of both flours were reduced to the 20-μm level, the bridging threshold levels were practically identical (43.5 and 45 g of force). This is further evidence for the importance of cohesion as a controlling factor for flour sieving index. These results also show that soft wheat flour surface characteristics are an important factor in explaining the differences in sieving indexes for hard and soft wheat flour.

CONCLUSION

The sieving index for hard and soft wheat flour was controlled by the cohesiveness of the flour system. The bulking number and bridging threshold tests identified that moisture content, presence or absence of fat, or particle size distribution and particle surface roughness, were involved in flour cohesion. Hard and soft wheat flour did not have the same sieving indexes until these four characteristics were held at equivalent values.

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