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FACTORS INFLUENCING THE DECORTICATION OF HIGH OIL CONTENT SUNFLOWER SEED

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Abstract

The hulling efficiency of a high oil cultivar sunflower seed with or without pretreatment was evaluated by using a small air-jet impact huller. Various pretreatments of seed studied included: sizing, heating, cooling, drying, moisture addition and combinations of these. Results indicated that sizing of seed and removing moisture from seed were most effective pretreatments of seed before hulling. Amount of unhulled seed (UHS) decreased from 35.5% to 13.8% when seed size increased from 4.8 mm to 7.9 mm. When a fixed size fraction of seed, between 5.6 mm and 6.4 mm, and a specific set of conditions for air-jet huller were used, the unhulled seed fraction decreased rapidly with increased heating time of seed at 190°C. It dropped from 28.35% to 14.6% within three minutes.

Introduction

Currently, the most commonly used technique to remove oil from sunflower seed is so-called pre-press solvent extraction process which produces a defatted meal with too much crude fiber and that is too black to be desired as a food ingredient. The only solution fro the production of a food grade sunflower seed meal is first to produce hull-free kernels and then to remove the oil. Therefore, the first question to be answered is how can low hull content or hull-free kernels be produced more efficiently.

Sallans and Sinclair (1) reported work on the dehulling of confectionary seed with a laboratory huller of the impact type. They found that low moisture levels (8%) with higher impact velocities produced by huller speeds of 3000 rpm and above gave almost complete hulling but with high meat breakage. Higher moisture levels (10-12%) gave practically no breakage of meats but low hulling efficiency in terms of percentages of seed hulled.

Later, Sinclair and Sallans (2) investigated flash drying of confectionary seed and found this gave a slightly lower percentage of seed hulled, with a definite decrease in the percentage of meats broken. Furthermore, the damaged meats were not broken into as small pieces as previously. For reasons that higher hulling efficiency was not achieved by flash drying were postulated by the authors to be as follows: 1) even though the hull is drier and more brittle, the additional support furnished by the meat due to the shrinking hull tends to resist the shattering effects of impact; 2) sunflower hulls have a light, spongy interior lining which becomes tough after absorbing moisture during the cooling period and this lessens the shattering effect of impact.

Popova, et al (3) studied the physical and mechanical properties of seed of high and low oil content. The genetic development of high oil sunflower seed resulted in changes in the chemical, morphological, physical and mechanical characteristics of the hull. As seed size decreases, hull thickness decreases. It was noted that deformation with increasing static load increased faster for high oil seed than for low oil seed. Increasing moisture in seed enchanced the flexibility of the hull and reduced the differences between similar types of seed from different lots in load-deformation tests. The hulls of low oil seed, in spite of greater thickness were shown to be more easily broken under static pressure. They found that it required the lowest force to break seed with the load directed along the axis of symmetry. The optimum speeds for a centrifugal type huller operating on representative high oil and low oil seed were found to be 37 and 35 m/sec respectively.

Drying of seed tended to promote easier breakage and spearation of hulls of high oil sunflower seed. However, drying of low oil seed did not cause significant changes in hulling results. Many fine particles from broken kernels and hulls were produced during the hulling of very dry seed, so it was desirable to dry the hulls without drying the kernels. This could be achieved with intensive heating for a short period of time. To produce good hulling the authors recommended:

- fractionating the seed so that seed going to the huller were uniform in size, moisture and other properties;

- subjecting the seed to a short, intensive drying step immediately before hulling;

- orienting the seed into the same position toward the impact surface in a huller.

Tholly (4) described a patented new procedure to decorticate sunflower seed using a gaseous pressurized fluid to break the hulls. However, no data were given on application of this process. Defromont (5) employed a commercial beater-type impact huller, similar to a flat blade blower. He described the overall results which coulc be obtained using this huller in combination with a kernel and hull separation process in an oil mill. No data is available on the amount of unhulled seed in the kernel fraction.

Belaborodov, et al (6) compared a beating-type huller with a centrifugal impact huller for decorticating high oil seed and concluded that the industrial prototype centrifugal huller gave better hulling efficiency by the mechanism of a single impact through the longitudinal axis of seed. The effectiveness of hulling also depends upon the moisture content and sizing of seed into narrow size ranges.

The above literature review indicates that the best possible hulling mechanism for sunflower seed is impact type, and that the size and moisture content of seed are important factors to yield good hulling results. The purposes of this report are: to describe a simple and economical air-jet impact huller, to suggest a method to evaluate hulling efficiency, and to report on an investigation of factors influencing the decortication of high oil sunflower seed.

Materials and Methods

Romsun HS-52, 1975 crop, high oil seeds were procured from Plains Co-operative Oil Mill, Lubbock, Texas. The seeds were cleaned and sized on a Bauer No. 199 cottonseed cleaner. Seed size distribution was determined with a series of round hold screens with diameters of 2.4, 3.2, 4.0, 4.8, 5.5, 6.4, 7.1 and 7.9 mm. The seed fraction (passing through 6.4 mm but remaining on 5.5 mm round hold screen) used for pretreatment and hulling tests contained 46.0% oil, 20.9% protein and 17.1% crude fiber in moisture free basis. The moisture content was 6.9% (dry basis). The seed consisted of 25.3% of hull which had a thickness of 0.29 ± 0.03 mm (11.4 ± 1.4 thousandths of an inch).

An air-jet huller similar to the one reported by Kirk and McLeod (7) was constructed. This allowed the use of small quantities of seed and gave reproducible results. The huller, Figure 1, was comparised of an air pressure regulator and gage connected to a modified plug valve through which the seeds were introduced into a straight pipe 1.6 cm inside diameter and 2.44 meters long. The impact target was an ordinary red building brick. Fine particle loss was prevented by enclosing the impact brick in a wire cage. The cage was placed inside a fiber drum to further prevent fine particle loss.

Hulled seed were collected, weighed, and screened over two round hole screens and a pan. The material remaining on the top screen, 4.0 mm and designated as 4.0 R, was sorted into UHS, kernels and hulls. The fraction remaining in the second screen, 2.4 mm and designated as 2.4 R, and the pan were not sorted.

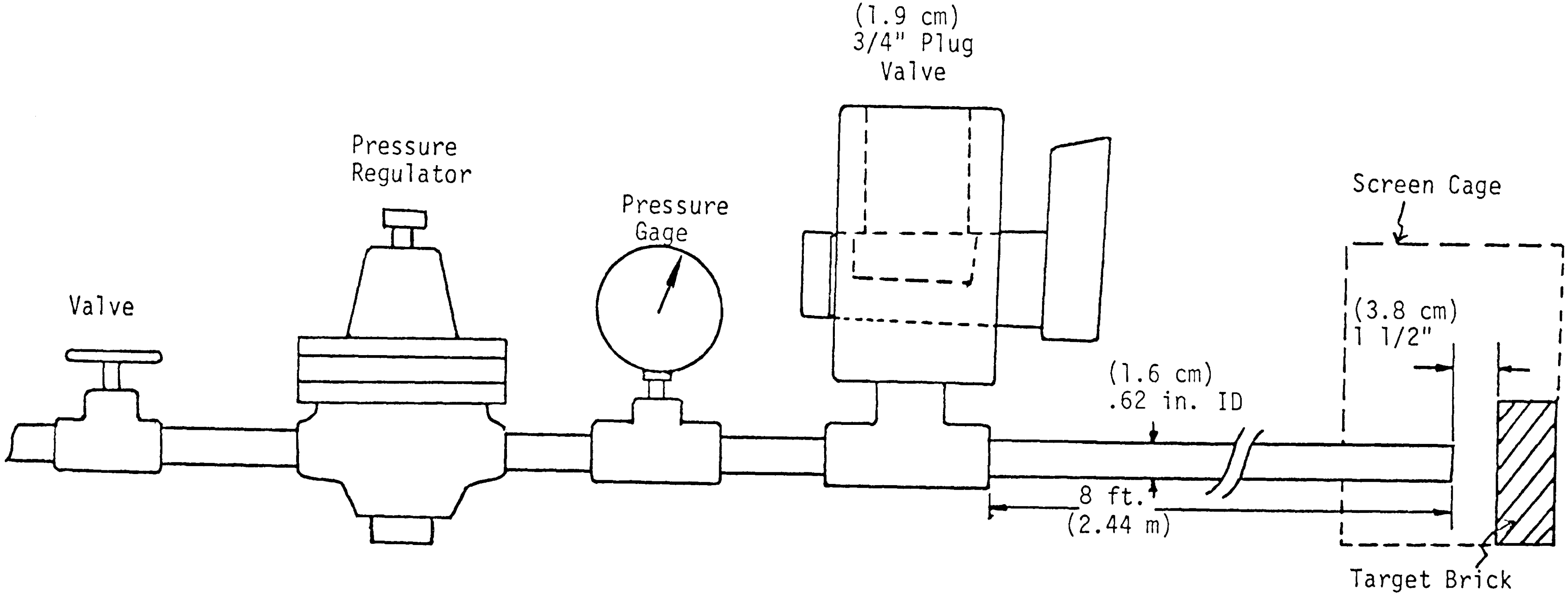
A circulating air oven was used for heating a 50 g seed sample. The oven temperature was regulated at 190±5°C. Heat treated seed was then cooled to room temperature in a closed chamber and weighed before hulling. Seed treated in refrigerator (5°C) was warmed up to room temperature in a similar procedure before hulling. Addition of moisture to seed was done by either direct spraying water on seed or steaming the seed. The wetted sample was kept in a closed chamber for 20 minutes and weighed before hulling. Some of the seed was dried in a desiccator without excessive heating. Weight loss or gain of seed after each treatment was examined before hulling and counted as moisture loss or gain. The weight loss after hulling was also monitored and generally was around 2% of the original weight of seed sample. Therefore different fractions for the evaluation of hulling efficiency were calculated without correcting the weight loss.

Results and Discussion

Hulling Efficiency and Huller Setting

Hulling efficiency needs to be defined in terms of the products which could be produced from the separation process. A definition of hulling efficiency is difficult to specify in terms of a single number. In a continuous hulling-separating process, material containing most of the unhulled seed (UHS) would probably be recycled to the original huller or would go to a second huller. This fraction in our work was material remaining on the 4.0 mm (10/64 inch) screen, consisting of unhulled seed, large kernels and large hulls. Material passing through the 4.0 mm screen would be subjected to separation pro-

FIGURE 1. Diagram of Air Jet Impact Huller.



cesses to produce relatively pure kernels and hulls. In our screen analysis these fractions (H + K) were those remaining on the 2.4 mm (6/64 inch) screen. A fraction of fine kernels and hulls (H + K) too small to be separated would be produced, and in our work this was taken to be material passing the 2.4 mm screen and collected in the pan. Complete decortication of all seed in one huller pass with no fines would be the ideal, however, this is difficult to achieve.

Unhulled seed (UHS) can be decreased by changes in huller settings as well as by pretreatments, but usually fines are increased at the same time. The reverse is also true. UHS cannot be increased too much or recycle load becomes excessive. Therefore for this study we were seeking hulling improvements which would not raise UHS above 30% of the sample and which in general would minimize the sum of UHS plus fines. This would rapidly eliminate conditions which produced either UHS or fines which were so high as to make the condition impractical.

The sum of UHS plus fines, at levels of UHS less than 30% of the sample, thus became our measure of hulling efficiency, to use in determining whether a particular pretreatment offered any promise. The air-jet huller was considered to be a device for rapid screening of pretreatment conditions. Any promising pretreatment would have to be evaluated for larger scale tests.

Table 1 shows data on all five fractions which were separated from hulled seed in all tests. To simplify the presentation of the hulling data, only three fractions, UHS and K on 4.0 R and (H + K)< 2.4 R, are reported for the remaining tables. Average of two or more tests for each set of hulling conditions was reported unless mentioned otherwise.

TABLE 1. Results of hulling by air jet impact huller with two variables: air pressure and target distance. Seed cultivar: Romsun HS-52.

		Fraction, %					
Condition		UHS on 4.0 R (1)	H on 4.0 R (2)	K on 4.0 R (3)	H+K on 2.4 R (4)	H+K <2.4 R (5)	(1)+(5)
Air pressure (All at 3.8 cm target distance)							
psig	N/m^2						
70	4.8×10^5	6.7	4.6	18.3	43.1	27.3	34.0
60	4.1	14.8	16.0	27.7	31.9	9.6	24.4
50	3.4	27.1	15.0	29.1	21.4	7.4	34.5
40	2.7	39.5	14.1	28.0	13.0	5.4	44.9
Target distance (all at 3.4×10^5 N/m^2)							
inch	cm						
1	2.5	15.8	14.6	23.8	33.2	12.6	28.4
1.5	3.8	27.1	15.0	29.1	21.4	7.4	34.5
3	7.6	27.8	14.8	27.8	22.6	7.0	34.8

UHS = unhulled seed including pieces of kernel with hull attached to it.
H = pure hulls
K = pure kernels
H+K = broken hulls and kernels

After the air-jet huller was constructed the first question addressed was what should be the air pressure used and did the distance between the end of the pipe and the target brick affect the results. The hulling results for several pressures and distances between the outlet pipe and target brick (impact gap) are shown in Table 1. The percentage of UHS (unhulled seed) decreased while percentage of fines (Hulls and Kernels 6/64 inches) increased with increasing pressure. A small impact gap produced more fines.

The standard deviations for various fractions were 2.2% for UHS on 4.0 R, 0.3% for pure hulls (H) on 4.0 R, 1.4% for pure kernels (K) on 4.0 R, 1.7% for broken hulls and kernels (H + K) and 2.4 R and 1.2% for fine particles of hulls and kernels (H + K) < 2.4 R. This indicated that the air-jet huller gave reasonably reproducible results.

Among the settings studied, 4.1×10^5 N/m^2 pressure and 3.8 cm target distance gave the lowest amount of UHS and fines. For investigation of pretreatments of seed, air-jet huller settings were arbitrarily fixed at 3.4×10^5 N/m^2 air pressure and 3.8 cm impact gap. Hulling results given under these conditions have room for possible improvement by pretreatment to be shown.

Seed Size

All lots of sunflower seed have a wide range of sizes. Seed size has an effect on hulling efficiency, as seen in Table 2. Amount of UHS decreases with increasing seed size, while fines are relatively constant. As seed size increases from 4.8 to 7.9 mm, the percentage of kernels larger than 4.0 mm doubles. This indicates that larger seed are easier to hull and yield more large kernels.

For study of pretreatments, the major size range, remaining on 5.6 mm and passing 6.4 mm, was used in all the remaining trials.

TABLE 2. Effect of seed size on hulling efficiency.

Seed Remaining on Screen Size, Diameter of Round Holes		Weight %	Fraction, %			
			UHS on 4.0 R (1)	K on 4.0 R (2)	H + K < 2.4 R (3)	(1)+(3)
inch	mm					
20/64	7.9	1.5	13.8	36.5	7.8	21.6
18/64	7.1	9.0	13.6	34.6	9.4	23.0
16/64	6.4	28.2	19.2	30.9	9.4	28.6
14/64	5.6	34.0	28.3	27.6	7.7	36.0
12/64	4.8	14.5	35.5	18.4	9.7	35.2

Effect of Various Treatments of Seed on Hulling Efficiency

The different pretreatments given to sized seed were described under Materials and Methods and hulled by air-jet impact huller at 3.4×10^5 N/m^2 pressure and 3.8 cm target distance. Data from these are tabulated in Tables 3 through 8.

TABLE 3. Influence of adding moisture to seed on hulling efficiency.

Added Moist. %, DB[a]	Total Moist. %, DB[a]	Fraction, % UHS on 4.0 R (1)	K on 4.0 R (2)	H + K < 2.4 R (3)	(1) + (3)
Direct addition of moisture					
16.7	23.6	90.6	6.3	0.2	90.8
8.6	15.5	88.9	6.9	0.4	89.3
1.2	8.0	56.4	21.2	3.2	59.6
Addition of moisture by steaming					
7.3	14.1	88.1	8.2	0.2	88.3
2.6	9.4	71.5	19.1	0.7	72.2
0	6.9	28.3	27.6	7.7	36.0

[a] DB = Dry Basis.

TABLE 4. Effect of cooling sunflower seed at 5°C for various periods of time on hulling efficiency.

Cooling time (hr) at 5°C	% Moisture (DB) before hulling	Fraction, % UHS on 4.0 R (1)	K on 4.0 R (2)	H + K < 2.4 R (3)	(1) + (3)
Under closed atmosphere					
4	7.0	28.6	27.2	7.9	36.5
23	6.6	27.7	27.3	8.0	35.7
71	7.0	30.6	28.6	7.2	37.8
Under open atmosphere					
0	6.9	28.3	27.6	7.7	36.0
4	7.0	33.0	27.9	5.7	38.7
23	7.7	45.2	29.9	2.6	47.8

TABLE 5. Influence of preheating of sunflower seed on hulling efficiency.

Time in 190°C oven (min)	% Moisture (DB) before hulling	Fraction, % UHS on 4.0 R (1)	K on 4.0 R (2)	H + K < 4.0 R (3)	(1) + (3)
0	6.9	28.3	27.6	7.7	36.0
1	6.3	25.2	27.1	10.0	35.2
1.5	6.0	21.1	26.3	12.2	33.3
2	5.6	15.5	26.4	14.3	29.8
2.5	5.3	14.6	25.0	16.3	31.9
4	3.5	5.9	15.9	32.1	38.0
6	2.3	5.3	16.9	28.9	34.2
8[a]	1.5	1.6	16.5	30.6	32.2
10[a]	0.6	0.8	15.4	34.1	34.9

[a] Single test.

TABLE 6. Results of hulling by air-jet impact huller. Pretreatment: drying at 190°C for 2 minutes.

Condition	% moisture (DB) before hulling	Fraction, % UHS on 4.0 R (1)	K on 4.0 R (2)	H + K < 4.0 R (3)	(1) + (3)
No treatment	6.9	28.3	27.6	7.7	36.0
Cooled in closed container	5.6	15.5	26.4	14.3	29.8
Heating and immediately hulling	2.4	10.3	22.8	21.4	31.7
Heating and cooling with blowing air	2.3	6.3	20.7	24.6	30.9

TABLE 7. Results of air-jet impact huller. Pretreatment: drying at 190°C or in desiccator.

Condition	% moisture (DB) before hulling	Fraction, % UHS on 4.0 R (1)	K on 4.0 R (2)	H + K < 4.0 R (3)	(1) + (3)
No treatment	6.9	28.3	27.6	7.7	36.0
Dried at 190°C for 2 min and cooled in closed chamber	5.6	15.5	26.4	14.3	29.8
Dried in desiccator - moisture loss equivalent to 2 min. heating at 190°C	-	18.2	26.2	13.8	32.0
Dried at 190°C for 4 min and cooled in close chamber	3.5	5.9	15.9	32.1	38.0
Dried in desiccator - moisture loss equivalent to 4 min. heating at 190°C	-	7.1	21.7	22.6	29.7

TABLE 8. Results of hulling by air-jet impact huller. Pretreatment: direct addition of moisture, then drying at 190°C for 2 minutes.

% Moisture Added	% Moisture (DB) before hulling	Fraction, % UHS on 4.0 R (1)	K on 4.0 R (2)	H + K < 2.4 R (3)	(1) + (3)
No treatment	6.9	28.3	27.6	7.7	36.0
0.0	5.6	15.5	26.4	14.3	29.8
0.5	4.9	18.3	29.0	11.2	29.5
1.2	6.3	22.0	28.8	9.8	31.8
2.0	6.3	27.1	28.0	8.8	35.9
4.0	7.7	34.9	34.2	4.3	39.2

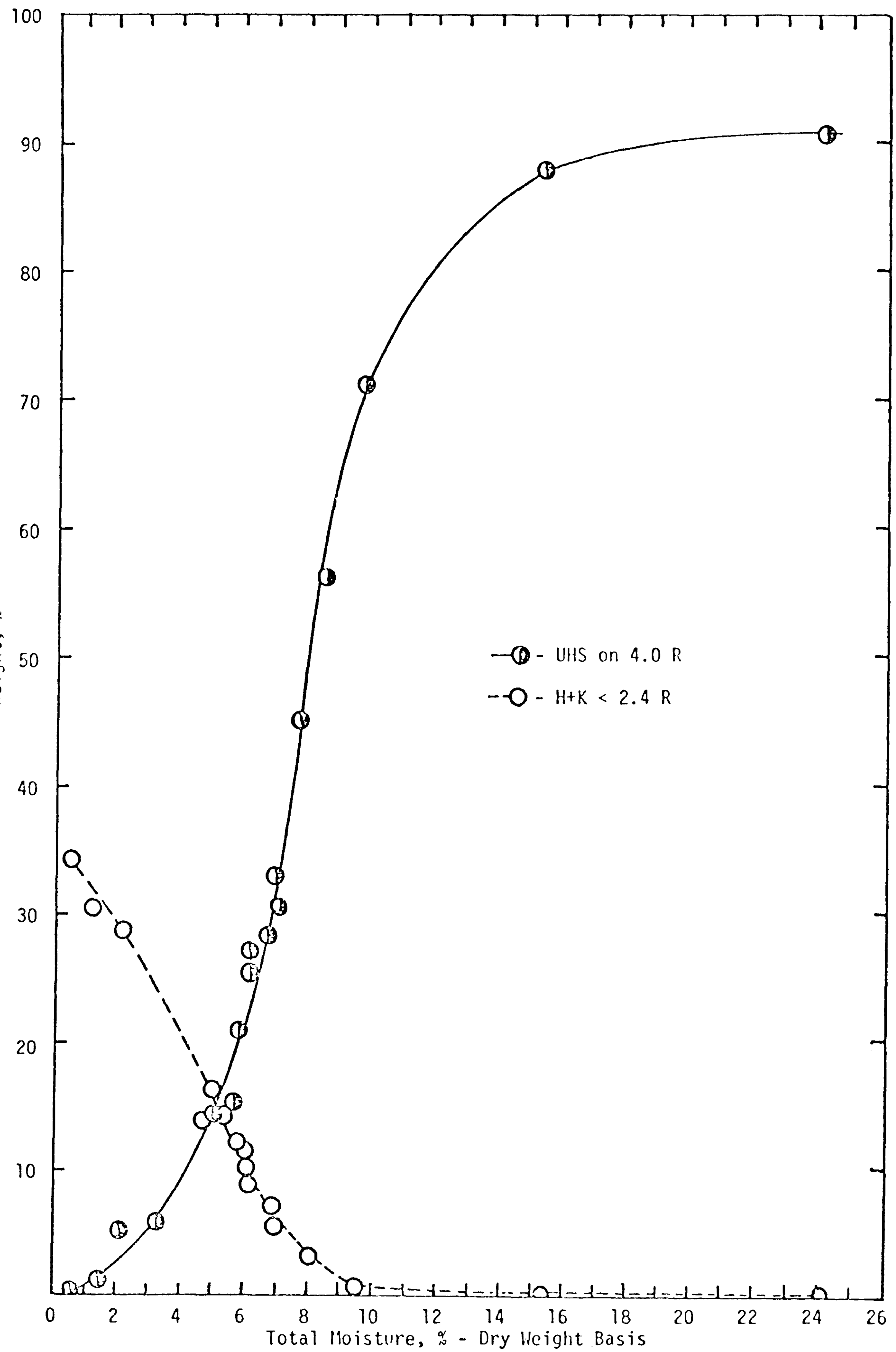


FIGURE 2. Plot of percentage of unhulled seed (UHS) on 4.0 R screen or broken hulls and kernels (H + K) smaller than 2.4 R screen versus percentage of moisture (dry weight basis) in seed before hulling by air-jet impact huller.

Results indicated that hulling efficiency decreases as moisture content of seed increases. Rapid or flash heating increases hulling efficiency by drying the hull. Longer heating also dries the kernel resulting in more broken kernels and fines. Removal of moisture from seed without heating gave similar results. Nearly complete hulling is possible if large quantities of fines are acceptable. Improved hulling efficiency cannot be achieved by adding moisture and then flash heating.

When plotting percentage of UHS and fines fraction against moisture in seed at hulling, Figure 2, it indicates that any pretreatment that removes moisture from seed will improve hulling efficiency. Those pretreatments with moisture added to the original seed before hulling will decrease the hulling efficiency or increase the amount of UHS. From the graph, the moisture of seed has to be kept to 7% or lower in order to have less than 30% UHS for the huller setting and seed size as specified.

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