AE-905 (Revised)

Grain Moisture Content Effects and Management

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Grain moisture content affects the quantity of grain, price discounts and premiums, as well as grain storability, so moisture content may affect economic return.

Moisture Content

Grain moisture content is expressed as a percentage of moisture based on wet weight (wet basis) or dry matter (dry basis). Wet basis moisture content is generally used. Dry basis is used primarily in research.

$$\text{Mw (wet basis)} = \frac{w - d}{w} \times (100)$$

$$\text{Md (dry basis)} = \frac{w - d}{d} \times (100)$$

w = wet weight
d = dry weight
M = moisture content on a percent basis

A representative sample must be obtained to provide a useful moisture content evaluation. Also, the moisture content of the product must be maintained from the time the sample is obtained until the determination is made by storing in a sealed container.

The moisture content can be determined by an oven method, which is a direct method. The grain is weighed and dried, then weighed again according to standardized procedures. The moisture content is calculated using the moisture content equations. Most moisture meters measure the electrical properties of grain, which change with the moisture content. This is considered an indirect method and must be calibrated by a direct method. It is important to follow moisture meter directions carefully to achieve an accurate moisture test. A moisture meter should be periodically checked to see if it is accurate. One method of checking the meter is to compare it to at least two other meters.

Grain Quantity

Changing the moisture content of grain changes its weight. This change is normally called "shrink" when grain is dried. The moisture shrink is calculated using the following equation.

$$\text{Moisture Shrink (\%)} = \frac{Mo - Mf}{100 - Mf} \times 100$$

Mo = original or initial moisture content (%)
Mf - final moisture content (%)

The moisture shrink when drying sunflower from 15 percent to 10 percent moisture content is:

$$\text{Moisture Shrink (\%)} = \frac{15 - 10}{100 - 10} \times 100 = 5.56$$

One hundred pounds of sunflower at 15 percent moisture would weigh 94.44 pounds after drying to 10 percent moisture [(100 lb – (5.56 percent x 100 lb)].

Many times a shrink factor is used to determine the amount of weight lost during drying. The shrink factor is the average shrink per point of moisture removed. In the sunflower example, the shrink was

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MARCH 1995

5.56 percent when the sunflower was dried five percentage points. The shrink factor then is 1.11 percent (5.56 divided by 5). The shrink factor depends on the final moisture content. Some shrink factors are listed in Table 1. If wheat is dried from 17.5 percent to 13.5 percent, the shrink factor is 1.1561 percent and the moisture shrink is 4.62 percent (1.1561 x 4 percentage points).

The same principle applies to moisture contents below the market standard. Wheat at 11 percent moisture has a moisture shrink factor of 1.1236. Therefore, wheat at 11 percent moisture rather than 13.5 percent will have a moisture shrink of 2.809 percent. Sixty pounds of wheat at 13.5 percent moisture content will weigh 58.31 pounds at 11 percent [60 – (2.5 x 1.1263 percent x 60)]. Table 2 shows the pounds of grain needed to equal a bushel at market standard moisture contents.

Table 1. Moisture shrink factors for drying grain to various moisture levels.

Final Moisture Content	Moisture Shrink Factor (% shrink per point moisture removed)
15.5	1.1834
15.0	1.1765
14.5	1.1696
14.0	1.1628
13.5	1.1561
13.0	1.1494
12.5	1.1429
12.0	1.1364
11.5	1.1299
11.0	1.1236
10.5	1.1173
10.0	1.1111
9.5	1.1050
9.0	1.0989
8.5	1.0929
8.0	1.0870
7.5	1.0811
7.0	1.0753
6.0	1.0638
5.0	1.0526
4.0	1.0417
3.0	1.0309
2.0	1.0204
1.0	1.0101
0	1.0000

The following equation shows the adjustment in quantity due to a change in moisture content.

$$\text{Adjusted Quantity} = \frac{100 - \text{Actual Moisture (\%)}}{100 - \text{Base Moisture (\%)}} \times \text{Measured Quantity}$$

One thousand pounds of wheat at 17.5 percent moisture would weigh 954 pounds at 13.5 percent.

$$\text{Adjusted Quantity} = \frac{100 - 17.5}{100 - 13.5} \times 1000 = 954 \text{ pounds}$$

Also, 1000 pounds of wheat at 11.0 percent moisture would weigh 1029 pounds at 13.5 percent.

$$\text{Adjusted Quantity} = \frac{100 \times 11}{100 - 13.5} \times 1000 = 1029$$

Sometimes the term "shrink" causes confusion because it is used to refer to things other than moisture shrink. When grain is handled through a facility, there will normally be losses due to dust, grain and foreign material that are spilled or grain that is damaged. Usually this is about 0.25 to 0.5 percent and is considered handling loss. Handling loss is often added to moisture shrink by the grain trade and called shrink.

A drying cost is required if wet grain is to be dried to the market standard. It will cause confusion if this is added to the moisture shrink and just labeled shrink. Grain at a moisture content above the market standard that is not dried prior to sale may be subject to a moisture discount that equals the sum of the moisture shrink and drying cost. Handling loss is also commonly included as part of the moisture discount by the grain trade.

Correct terminology helps to avoid confusion. Moisture shrink, handling loss, and moisture discount describe specific and different things.

The following example shows the various terms applied to 20,000 pounds of 15 percent moisture sunflower valued at $10 per hundredweight (cwt) with 2 percent foreign material.

Table 2. Weights to equal a bushel at market standard moisture contents.

Moisture Content (%)	Wheat	Sunflower CWT	Corn	Barley	Oats	Rye	Beans
5.0	54.63	94.73	49.81	43.20	28.97	50.69	54.95
5.5	54.92	95.24	50.07	43.43	29.12	50.96	55.24
6.0	55.21	95.74	50.34	43.66	29.28	51.23	55.53
6.5	55.51	96.26	50.61	43.89	29.43	51.51	55.83
7.0	55.81	96.78	50.88	44.13	29.59	51.79	56.13
7.5	56.11	97.30	51.16	44.37	29.75	52.07	56.43
8.0	56.42	97.83	51.44	44.61	29.91	52.35	56.74
8.5	56.72	98.36	51.72	44.85	30.08	52.63	57.05
9.0	57.03	98.90	52.00	45.10	30.24	52.92	57.36
9.5	57.35	99.45	52.29	45.35	30.41	53.22	57.68
10.0	57.67	100.00	52.58	45.60	30.58	53.51	58.00
10.5	57.99	100.56	52.87	45.85	30.75	53.81	58.32
11.0	58.31	101.12	53.17	46.11	30.92	54.11	58.65
11.5	58.64	101.69	53.47	46.37	31.10	54.42	58.98
12.0	58.97	102.28	53.77	46.64	31.27	54.73	59.32
12.5	59.31	102.86	54.08	46.90	31.45	55.04	59.95
13.0	59.65	103.46	54.39	47.17	31.63	55.36	60.00
13.5	60.00	104.05	54.71	47.45	31.82	55.68	60.35
14.0	60.35	104.66	55.02	47.72	32.00	56.00	60.70
14.5	60.70	105.26	55.35	48.00	32.19	56.33	61.06
15.0	61.06	105.89	55.67	48.28	32.38	56.66	61.41
15.5	61.43	106.52	56.00	48.57	32.57	57.00	61.78
16.0	61.79	107.15	56.33	48.86	32.76	57.34	62.14
16.5	62.16	107.79	56.67	49.15	32.96	57.68	62.52
17.0	62.53	108.44	57.01	49.45	33.16	58.03	62.89
17.5	62.91	109.10	57.36	49.75	33.36	58.38	63.28
18.0	63.30	109.76	57.71	50.05	33.56	58.74	63.66
18.5	63.69	110.44	58.06	50.36	33.77	59.10	64.05
19.0	64.08	111.11	58.42	50.67	33.98	59.46	64.45
19.5	64.47	111.81	58.78	50.98	34.19	59.83	64.85
20.0	64.88	112.51	59.15	51.30	34.40	60.20	65.25
21.0	65.70	113.93	59.90	51.95	34.84	60.96	66.08
22.0	66.54	115.39	60.67	52.62	35.28	61.75	66.93
23.0	67.41	116.89	61.45	53.30	35.74	62.55	67.80
24.0	68.29	118.43	62.26	54.01	36.21	63.37	68.69
25.0	69.20	120.00	63.09	54.73	36.69	64.22	69.61
26.0	70.14	121.62	63.95	55.47	37.19	65.09	70.55
27.0	71.10	123.29	64.82	56.22	37.70	65.98	71.51
28.0	72.10	125.00	65.72	57.00	38.22	66.89	72.51
29.0	73.10	126.77	66.65	57.80	38.76	67.84	73.53
30.0	74.15	128.58	67.60	58.63	39.31	68.80	74.58

Brackets indicate the weight at the market standard moisture content.

Determine Moisture Discount

Moisture Shrink Factor (10% moisture content, Table 1)	1.111%/pt.
* Drying Cost	
— energy: 2.5¢/pt. • cwt. x 5 pt.	= 12.5¢
— annual ownership: 18% of dryer initial cost/cwt.	= 20.0¢
	32.5¢/cwt.
32.5¢/cwt. ÷ $10.00/cwt. ÷ 5 pt.	0.650%/pt.
	1.761 %/pt.

Sunflower Price – $10.00/cwt.
pt. – Percentage Point of Moisture Removed

*Circular AE-923 Calculating Grain Drying Cost, NDSU Extension Service

Reductions to Gross Weight	Pounds
Gross Weight	20,000
Foreign Material(2%)	– 400
Gross Clean Weight	19,600
Moisture Discount 1.761%/pt. x 5 pt. x 19,600	– 1,726
Handling Loss 0.5% x 19,600	– 98
Net Dry Clean Sunflower	17,776

The moisture discount is commonly calculated on the gross weight rather than the gross clean weight. This produces an additional reduction in weight for marketing grain with foreign material (1.761 % x 5 pt. x 20,000 = 1761; 1761 – 1726 = 35). This is an attempt to cover the cost of drying the foreign material and cleaning the grain or additional freight expense during marketing.

Market Value

A bushel is a volume of 1.244 cubic feet. However, grain is marketed by bushels based on a standard weight per bushel. For example, 60 pounds of wheat is a bushel at the standard of 13.5 percent moisture content.

Changes in moisture content affect the quantity of dry matter in a bushel of grain. Dry matter contains the nutrients (protein, fat, oil and carbohydrates) which are feed for animals or food for people. Think of a sponge to understand dry matter and moisture. When completely dry, a sponge is 100 percent dry matter. The addition of water makes the sponge heavier. To maintain the initial weight, some dry matter must be removed. Table 3 shows how the change in moisture content affects the pounds of water and dry matter in a bushel determined by weight and the economic return per pound of dry matter.

Test Weight

A change in the moisture content will also change the test weight of grain. The test weight is the weight per bushel based on volume. Since grain volume changes with a change in moisture content and since water and dry matter do not weigh the same, the test weight is changed. Table 4 shows how test weight is affected by moisture content.

Test weight can be adjusted for changes in moisture content by using the following equation:

$$\text{Adjusted Weight} = \frac{100 - \text{Adjusted M.C. (\%)}}{100 - \text{Actual M.C.(\%)}} \times \text{Measured Weight}$$

The test weight of wheat at 13.5 percent moisture content is 59.76 pounds per volume bushel if the measured test weight is 57.00 pounds at 17.5 percent moisture content.

$$\text{Adjusted Weight} = \frac{100 - 13.5}{100 - 17.5} \times 57 \text{ lb.} = 59.76 \text{ lb.}$$

This adjustment is only accurate if the physical structure of the kernel is not affected. For example, corn may not show an increase in test weight during drying if the kernel is cracked or broken. The test weight of the corn with broken kernels may be less than the test weight before it was dried. The adjusted test weight should be considered a reasonable estimate.

Table 3. Effect of moisture content on a bushel of marketed grain.

Grain	Weight (lb.)	Moisture Content (%)	Water (lbs.)	Dry Matter (lbs.)	Price/bu. ($)	Moisture Discount (2%/pt.bu.) ($)	Dry Matter Price (–/lb)
Corn	56	18.5	10.36	45.64	3.00	0.18	6.18
Corn	56	*15.5	8.68	47.32	3.00	0.00	6.34
Corn	56	12.5	7.00	49.00	3.00	0.00	6.12
Wheat	60	16.5	9.90	50.10	3.50	0.21	6.57
Wheat	60	*13.5	8.10	51.90	3.50	0.00	6.74
Wheat	60	10.5	6.30	53.70	3.50	0.00	6.52
Soybeans	60	16.0	9.60	50.40	8.00	0.48	14.92
Soybeans	60	*13.0	7.80	52.20	8.00	0.00	15.33
Soybeans	60	10.0	6.00	54.00	8.00	0.00	14.81

Test Weight Grade Minimum Adjustments are not Considered.
*Market Standard Moisture Content

Table 4. Test weight variation due to moisture content.

Grain	Moisture Content (%)	Test Weight (lbs.)
Corn	13.5	57.33
	15.5	56.00
	17.5	54.67
Wheat	11.5	61.39
	13.5	60.00
	15.5	58.61

Percent Protein and Oil

The amount of protein in wheat, or oil in sunflower, is not affected by the moisture content. However, the percentage of oil or protein is affected due to the amount of water in the sample. The Federal Grain Inspection Service (FGIS) specifies that wheat protein percentage be stated at 12 percent moisture content and sunflower oil content percentage be stated at 10 percent moisture content. The standard moisture content eliminates the confusion that results if the protein or oil percentage is expressed on an as is basis.

The equation for adjusting both protein and oil content to the standard moisture content is:

$$\text{Adjusted Value} = \frac{100 - \text{Base M.C. (\%)}}{100 - \text{Actual M.C.(\%)}} \times \text{Measured (\%) Value}$$

The percent protein at 12 percent moisture content is 14.8 percent if the measured percent protein is 14.0 percent at 17 percent moisture content.

$$\text{Adjusted Protein} = \frac{100 - 12}{100 - 17} \times 14\% = 14.8\%$$

The percent of oil sunflower at 10 percent moisture content is 40.3 percent if the measured oil percentage is 39 percent at 13 percent moisture content.

$$\text{Adjusted Oil} = \frac{100 - 10}{100 - 13} \times 39\% = 40.3\%$$

Grain Storability

Grain moisture content does not directly affect grain quality but can indirectly affect quality since grain will spoil at moisture contents above that recommended for storage. Since both molds and insects require moisture to grow, grain stores better at lower moisture contents. The maximum recommended moisture contents for storage, with aeration, of some North Dakota crops are shown in Table 5. Proper storage management and good quality grain are required for safe storage at these moisture contents. The moisture content should be reduced for grain with broken kernels or with substantial amounts of dockage and foreign material.

Although grain stores better at lower moisture contents, kernel breakage may be more of a problem during handling.

Refer to Extension Circular AE-791 "Crop Storage Management" for more information.

Table 5. Maximum recommended moisture content for storage with aeration of some North Dakota crops.

Crop	Short Term (less than 6 months) (%)	Long Term (more than 6 months) (%)
Barley	14	12
Corn	15.5	13
Durum	13.5	12.5
Edible Beans	16	13
Flax seed	9	7
Millet	10	9
Oats	14	12
Rye	13	12
Sorghum	13.5	13
Soybean	13	11
Non-oil Sunflower	11	10
Oil Sunflower, 30-50% Oil	10	8
Wheat	14	13

Moisture Management

Managing grain moisture content is important to maximize economic return. As shown in Table 3, the maximum economic return is received by marketing at the market standard moisture content.

Grain must be dry enough for safe storage but overdrying is costly. At $3.50 per bushel, there is a loss of 12 cents per bushel if wheat is marketed at 10.5 percent rather than 13.5 percent moisture [(60 – 57.99)] x $3.50/bu divided by 60 lb/bu.)]. Harvesting some wheat above the recommended storage moisture content and mechanically drying it may reduce the amount that is overdried in the field. This may also allow more hours of harvesting per day. When mechanically drying grain, there is a double penalty for overdrying; the expense of drying and the loss of weight that can be sold.

Another option is to harvest wet grain and blend it with overdried grain. This requires more handling equipment and management but may eliminate the need for drying. When 1000 pounds of wheat at 14 percent moisture is blended (mixed) with 1000 pounds at 12 percent moisture, the moisture will equalize to produce 2000 pounds at an average of 13 percent moisture.

The grain must be thoroughly mixed together or wet spots will exist. Dry kernels must touch wet kernels for the moisture to equalize and the temperature must be above freezing. Moisture movement is enhanced at warmer temperatures. Aerating the grain will also aid in equalizing the moisture content. There will still be some moisture variation between kernels. The following equation can be used to determine quantities required for blending.

$$\text{Quantity Required for Blending} = \frac{DMC - KQMC}{DMC - QRMC} \times KQ$$

DMC = Desired Moisture Content
KQMC = Moisture Content of Known Quality
QRMC = Moisture Content of Quantity Required
KQ = Known Quantity of Grain (pounds or bushels)

For example, 2000 pounds of wheat at 11 percent moisture content is needed to blend with 10,000 pounds at 14 percent to get 12,000 pounds at 13.5 percent moisture content.

$$\text{Quantity Required} = \frac{13.5 - 14}{13.5 - 11} \times 10{,}000 = 2{,}000 \text{ pounds at } 11\%$$

There is an economic benefit for blending grain rather than marketing some overdried and some wet. The economic return for blending 1000 pounds of wet sunflower with 2000 pounds of overdried sunflower is $296 vs $300, as shown in Figure 1. The cost of blending due to operating additional equipment has not been included.

Increasing grain moisture content by using fans to force moist air through the grain may cause wet layers of grain and possibly bin structural failures. Since grain moisture content change occurs across a front, a layer of higher moisture grain will result if the fans are operated during periods when the relative humidity exceeds 70 percent. Figure 2 shows a wet layer in the top of a bin of wheat due to operating the fan pulling the air down during a period of high humidity.

Table 6 shows the average temperature and relative humidity in North Dakota for selected months and what the equilibrium moisture content for wheat would be under these conditions. Running fans for a long time in November under average conditions would result in a layer of 17 percent wheat in the bin. The grain should be cooled to 25 to 30 degrees Fahrenheit to prevent moisture migration, but that will only require a few hours of fan operation. Running the fan just long enough to cool the grain even under high humidity conditions would only rewet about 1/50th of the grain. Refer to Extension Circular

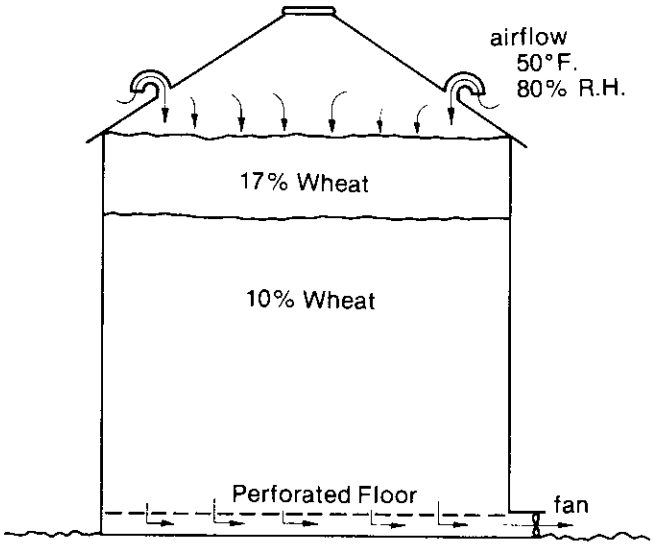

Figure 2. Wet layer caused by running fan during period of high humidity.

Table 6. North Dakota average temperatures and relative humidities, and corresponding wheat equilibrium moisture content.

Month	Temp (°F)	R.H. (%)	Wheat EMC (%)
August	69	60	13.3
September	58	65	14.5
October	47	65	15.0
November	27	73	17.3
March	24	73	17.6
April	42	65	15.3
May	56	60	13.9

Figure 1. Economic return for blending wet with dry sunflower.

1000 lb. 12% m.c. Moisture Discount = 2%/pt x 2 pt. x 1000 lb. = 40 lb. Paid 960 x 0.10 = $96	+	2000 lb. 9% m.c. 2000 x 0.10 = $200	VS.	3000 lb. 10% m.c. 3000 x 0.10 = $300

No cost for blending has been included.
Market price = 10 cents per pound
m.c. = moisture content

AE-791, "Crop Storage Management", for storage management information.

The increased value of wheat due to increased weight resulting from operating a fan to increase the wheat moisture content may or may not exceed the cost of running the fan. Table 7 shows the moisture added per hour, the moisture needed per bushel to increase the moisture content to 13.5 percent, fan operation time using an airflow rate of 0.2 cfm/bu. to increase the moisture content, wheat value added due to increased weight and fan operation cost. For example, the increase in wheat value due to increased weight for an initial moisture content of 10 percent is 34 cents per hour and the fan cost is 14 cents per hour of fan operation.

Note that the fan operation time of about 70 days changes very little whether the initial moisture content is 10 percent or 12 percent.

Table 7. Economic return for raising moisture content by fan operation with overdried wheat.

Initial M.C. (%)	Moisture Added (lb/hr)	Moisture Needed* (lb/hr)	Fan Time (days)	$3.00 Wheat Value Added (¢/hr)	Fan Cost (¢/hr)
10	6.82	2.33	71	34	14
11	5.07	1.69	69	25	14
12	3.18	1.03	67	16	14

5,000 bushels wheat 55°F. 60% R.H. EMC=13.9%
1HP Fan 0.20 cfm/bu.
Electricity 7 cents/KWH.
*13.5% Moisture Content

WARNING

Adding moisture to grain in a bin will increase the grain volume and may cause enough pressure to rupture a bin. Do not change the moisture content more than about two percentage points. Removing grain from the center of the bin periodically will help reduce the pressure increase if moisture is added to the grain.

Care must be used if water is added directly to grain it is removed from storage. It is imperative that the quantity of water required be calculated correctly, that the rate of application be calibrated, that the moisture content and quantity of grain coming from storage be checked frequently, and that there be thorough mixing. An error in any of these items will cause problems. Initially, the water added will be on the surface of the kernels causing an erroneous moisture content measurement, and the grain will have a very wet appearance. Research indicates that several hours are required for the moisture to equalize in the kernel.

NOTICE

The Food and Drug Administration considers grain to be adulterated if any substance has been added thereto or mixed with or packed therewith so as to increase its bulk, weight, or to reduce its quality, strength, or make it appear better or of greater value than it is. The present interpretation indicates it is illegal to add moisture to or blend grain.

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3M-2-95

AE-905