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# Inspection of Wheat Grain Samples Delivered to the Grain Silos and Flour Mills Organization in 1988-1989 with Emphasis on Insect Infestation

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ABSTRACT. Grain Silos and Flour Mills Organization (GSFMO) of Saudi Arabia is in charge of receiving farmer's annual yield of wheat grain that meet the standard specification established for wheat grain acceptance. In 1988 and 1989, 96 and 93% of the total wheat samples delivered were accepted respectively. Exceeding dockage content (max. limits 12%) was the most important reason for rejection, followed by insect infestation. The major components of dockage were barley (39%), wheat broken kernels (22.5%), shrunken kernels (19.2%), and weed seeds (15%). Four beetle species were detected in the infested samples. The most commonly occurring species was *Tribolium castaneum* (Herbst). The number of insects per 1 kg was relative low and was correlated with period of storage, and percentage of dockage. A discriminat analysis was used to differentiate between free infested and infested samples on the basis of five discriminating variables (moisture content, dockage, test weight, protein content, and the length of storage in weeks). The accuracy of this formula was 89.9-100% and 84.6-86.3% for free infested and infested samples respectively. The percentage of moisture content of wheat grain was the most powerful factor in distinguishing the infested from free infested samples followed by dockage, test weight, protein content, and period of storage.

Wheat grain production in Saudi Arabia increased steadily in the last decade. More than 3.2 million tons of wheat were produced in 1989 (GSFMO 1989). The expansion in wheat production was mainly due to governmental subsidy of wheat growers.

Several standard specifications were established for wheat grain to be accepted by the Grain Silos and Flour Mills Organization (GSFMO). These specifications remain relatively unchanged from year to year. Among the most important components of these specifications are: test weight (min. limits 67 kg/HL), moisture content (max. limits 12%), dockage (max. limits 12%) protein content (min. limits 7%) sand and stones (max. limits 0.5%). Wheat samples should be also completely free from insect infestation, colored seed and abnormal odor. Wheat samples which do not meet the forementioned specifications were rejected. Accepted wheat samples are divided into four subclasses mainly according to test weight, protein content, and the percentage of dockage.

The commercial wheat production in Saudi Arabia is relatively new. Therefore, the farmers, mainly small farmers, do not obtain enough experience to produce wheat grain which met the GSFMO specifications. The objectives of the current study were to inspect the wheat grain samples deliver to GSFMO, evaluate the wheat characteristics, determine reasons of samples rejections, and to discriminate between infested and uninfested samples on the basis of a set of discriminating variables.

## Materials and Methods

This study was carried out in the GSFMO and the Plant Protection Department Laboratories, College of Agriculture, King Saud University, Riyadh for two successive years; 1988 and 1989.

*Sampling:*

Apollo Mechanical Trier (Elevator Contractors, Inc. USA) was used to pick up a 2 kg sample of wheat from each loaded truck, at five points in a pattern of Z letter. A total of 17621 and 17029 samples were received by GSFMO in 1988 and 1989 respectively. Each sample was given a number (farmer's number) and then mechanically transferred to the laboratory for inspection.

Ten random samples of accepted wheat were weekly selected and analyzed in the laboratory. The reason of rejection was recorded for each rejected sample. A full Analysis was carried out for each rejected sample due to insect infestation. in 1989, eight rejected samples, due to dockage, were weekly selected and percentage of each dockage component was measured.

*Laboratory Analysis of Samples:*

Selected samples were inspected immediately after being received. Each wheat sample (2 kg) was sifted using a 1/12 in. (2.1 mm) round hole sieve

(Seedburo Equipment Company, USA) to separate adult insects. Insects were kept into a plastic vial with small amount of white flour for identification and counting. Insect number was expressed as the number of live adults per 1 kg. The fine particles, which passed through the sieve, were returned back to the sample.

Each sample (2 kg) was divided to obtain a representative sample of 1 kg by using a Precision divider (Gamet MFG, USA). The 1 kg sample was passed through a Dockage Tester (CEA. Carter-Day, USA). The dockage was weighted and the weight was expressed as a percentage. The percentage of moisture content was determined using a Digital Moisture Computer, Burrows (Seedburo Equipment Co., USA). Test weight was determined using Ohaus (Seedburo Equipment Co.). The percentage of protein content was determined with an Instalab 800 Nir Production Analyzer (Dicky-John International Co., USA).

*Statistical Analysis:*

Pearson Correlation Coefficient, General Linear Model (GLM), and discriminit Analysis Procedures were used with a program from the Statistical Analysis System (SAS Institute, 1982)

## Results

Grain Silos and Flour Mills Organization (GSFMO) of Riyadh plant received 17621 and 17029 loaded trucks with wheat grain in 1988 and 1989 respectively. 96 and 93% of those samples, respectively, met the GSFMO wheat specification and were accepted.

The analysis of accepted wheat samples in both years revealed that the Saudi wheat characterized by a relatively high protein content (14.1%), a high test weight (76.4), moderate moisture (7.1) and dockage content (5.1%) respectively (Table 1). The percentage of protein content and test weight were not significantly different in both years. However, the percentage of dockage content of 1989 was significantly higher than that dockage of 1988. In contrast, the percentage of moisture content of 1988 was significantly higher than the moisture content of 1989 (Table 1).

Before wheat grains be delivered to GSFMO, wheat grains are usually stored in farms. This period of storage varies according to the fixed date, in which each farmer has to deliver his wheat. Pearson Correlation Coefficient showed that this period has no significant effect on the percentage of dockage ($r = 0.01$, $P = 0.9$), protein content ($r = 0.01$, $P = 0.9$), or test weight ($r = 0.14$, $P = 0.18$). However,

the percentage of moisture content was significantly reduced with time ($r = -0.48$, $P = 0.001$).

The number of rejected samples was low. Only 4 and 7% of the total samples were rejected in 1988 and 1989 respectively. Exceeding dockage limitation (max. limits 12%) was the most important reason for rejection. 56.1 and 87.1%, of the total rejected samples were not accepted for this reason in 1988 and 1989 respectively. Samples rejected due to insect infestations constituted 25.8 and 2.1% of the total rejected samples in both years. Rejection due to sand (max. limits 0.5%) consisted of 10.6 and 6.4% of the total rejected samples. Rejection due to other factors (test weight, moisture and protein content) were extremely low (Table 2).

In 1989, the dockage components of rejected samples, due to dockage, included barley (39%), wheat broken kernels (22.5%), wheat shrunken kernels (19.2%), weed seeds (15%). Other components such as wheat dust, sand, stones, sprouted wheat kernels, black tip fungus, heated kernels weed seeds, and colored kernels were low (4.3%). Percentage of barley, broken kernel, shrunken kernels, and other components, each was significantly different from others as determined by GLM.

Samples rejected due to insect infestation were consisted of 25.8 and 2.1% of the total rejected samples for 1988 and 1989 respectively. Four insect species of beetles were occurred in the infested samples. The most commonly occurring species was *Tribolium castaneum* (Herbst) which was found in 62.8 and 57% of infested samples, *Rhizopertha dominica* (F.) was detected in 25.6 and 22.9% of infested samples in the 1988 and 1989 respectively. *Trogoderma granarium* (Evert) and *Laemophloeus* sp. was each found in less than 10% of infested samples.

Comparison between infested and uninfested samples, shows clearly that the infested samples were significantly characterized with high moisture content, high percentage of dockage,and low test weight. However, the percentage of protein content of infested samples and uninfested samples was not significantly different as determined by General Linear Model (Table 3).

The mean number of insects per 1 kg was relatively low for both years. The mean number of insects per 1 kg was 3.5 and 4.7 with a range of 1.3-5.2 and 2-10.5 for 1988 and 1989 respectively.

Pearson correlation coefficient procedure revealed that number of live insects per 1 kg was significantly correlated with time of sample delivery to GSFMO ($r = 0.32$, $P = 0.03$), percentage of dockage ($r = 39$, $P = 0.01$), and negatively correlated with percentage of moisture content ($r = -0.66$, $P = 0.0001$). However,

**Table 1.** Saudi wheat grain characteristics for 1988 and 1989

| Wheat Characteristics | Year | | mean ± SE |
|---|---|---|---|
| | 1988 | 1989 | |
| Test weight kg/HL | 76.5 a | 76.3 a | 76.4 ± 0.13 |
| % Protein content | 14.1 a | 14.1 a | 14.1 ± 0.13 |
| % Moisture content | 7.6 a | 6.5 b | 7.1 ± 0.1 |
| % Dockage | 4.4 a | 5.9 b | 5.1 ± 0.15 |

Means followed by the same letter for each characteristic were not significantly different as determined by GLM.

**Table 2.** Percentage of rejection for each specification from total rejected samples

| Specifications | Percentage | |
|---|---|---|
| | 1988 | 1989 |
| Dockage (max. limits 12%) | 56.1 a[1] | 87.1 a |
| Infestation | 25.8 b | 2.1 c |
| Sand (max. limits 0.5%) | 10.6 c | 6.4 b |
| Test weight (min. limits 67 kg/HL) | 3.2 d | 0.3 e |
| % Moisture (max. limits 12%) | 0.1 e | 0.0 e |
| % Protein (min. limits 7%) | 0.0 e | 0.0 e |
| Others[2] | 4.2 d | 4.1 d |

[1]Means followed by the same letter for same column were not significantly different as determined by GLM.

[2]Others included: mixed wheat, colored wheat, black fungus, and heated kernels.

**Table 3.** Wheat grain characteristics of infested and free infested samples

| Grain characteristics | Free infested samples (mean ± SE) | Infested samples (mean ± SE) |
|---|---|---|
| % Moisture content | 7.1 ± 0.2 a | 8.4 ± 0.1 b |
| % Dockage | 5.1 ± 0.2 a | 6.3 ± 0.5 b |
| Test weight | 76.4 ± 0.1 a | 75.6 ± 0.3 b |
| % Protein content | 14.2 ± 0.2 a | 14.0 ± 0.2 a |

Means with the same letter for same characteristics were not significantly different as determined by GLM.

insects number per 1 kg was not correlated with percentage of protein content (r = 3, P = 0.1), and test weight (r = −0.2, P = 0.21).

To discriminate between infested and free infested samples on the basis of a set of discriminating variables (moisture content, dockage, test weight, protein content, and period of storage in weeks), a discriminate formula (Morrison 1978) was used. The formula is:

$$W = x'S^{-1}(\bar{x}_1 - \bar{x}_2) - 1/2\,(\bar{x}_1 + \bar{x}_2)'S^{-1}(\bar{x}_1 - \bar{x}_2) \quad (1)$$

The $-1/2\,(\bar{x}_1 + \bar{x}_2)'S^{-1}(\bar{x}_1 - \bar{x}_2)$ = constant and it was calculated (Appendix 1). The equation 1 can be reduced to

$$W = x'S^{-1}(\bar{x}_1 - \bar{x}_2) + \text{constant}. \quad (2)$$

Where:

W = Wald-Anderson classification statistic (Wald 1944).

$S^{-1}$ = Inverse covariance matrix.

$\bar{x}_1$ = Mean of discriminating variables of the computed free infested samples.

$\bar{x}_2$ = Mean of discriminating variables of the computed infested samples.

x' = Discriminating variables of tested sample.

The tested sample is free infested if $W > 0$ and otherwise it is infested. The $S^{-1}(\bar{x}_1 - \bar{x}_2)$ was calculated for each discriminating variable and it is here called Eigenvalue for simplicity (Table 4 and Appendix 1).

**Table 4.** Eigenvalues and powerful of discriminating variables

| Discriminating Variables | Eigenvalue[1] | | | Powerful (%)[2] | | | mean |
|---|---|---|---|---|---|---|---|
| | 1988 | 1989 | 88+89 | 1988 | 1989 | 88+89 | |
| Moisture | 3.1 | 4.7 | 2.9 | 75.9 | 73.1 | 67.5 | 72.2 |
| Dockage | 0.3 | 0.8 | 0.5 | 7.2 | 12.3 | 11.7 | 10.4 |
| Test weight | 0.4 | 0.1 | 0.3 | 10.7 | 1.4 | 7.5 | 6.5 |
| Protein | 0.04 | 0.6 | 0.4 | 1.0 | 8.6 | 8.8 | 6.1 |
| Period of storage (weeks) | 0.2 | 0.3 | 0.2 | 5.2 | 4.7 | 4.5 | 4.8 |

[1]Eigenvalue is absolute values here. For Eigenvalues calculation see appendix 1.
[2]Powerful (%) = the relative percentage of Eigenvalue.

The accuracy of using the discriminate analysis to differentiate between infested and free infested samples was relatively high. The accuracy was 89.9 and 100% for free infested samples and 86.3 and 84.6% for infested samples for 1988 and 1989 respectively.

The discriminating variables had unequal power in determining the W value. The moisture content of wheat samples provided the greatest discriminating power among characteristics variables. The discriminating power of moisture content was 67.5-75.9% with a mean of 72.2. Whereas. The discriminating power of dockage was 7.2-12.3% with a mean of 10.4%. The discriminating power of test weight, protein content and time of samples delivery to GSFMO were low (Table 4).

**Appendix 1.** Constants and the $S^{-1}\bar{x}_1$, $S^{-1}\bar{x}_2$ and $S^{-1}(\bar{x}_1-\bar{x}_2)$ values of discriminating variables*

| Year | Variables | $S^{-1}\bar{x}_1$ | $S^{-1}\bar{x}_2$ | $S^{-1}(\bar{x}_1-\bar{x}_2)$ (Eigenvalue) |
|---|---|---|---|---|
| 1988 | % Moisture | 20.01 | 23.06 | −3.05 |
| | % Dockage | −1.16 | −0.87 | −0.29 |
| | Test weight | 36.91 | 36.48 | 0.43 |
| | % Protein | 47.98 | 47.94 | 0.04 |
| | Period of storage | 2.68 | 2.89 | −0.21 |
| | Constant | | | −5.19 |
| 1989 | % Moisture | 53.53 | 58.23 | −4.70 |
| | % Dockage | 23.68 | 24.47 | −0.79 |
| | Test weight | 74.94 | 75.03 | −0.09 |
| | % Protein | 67.11 | 66.56 | 0.55 |
| | Period of storage | 4.30 | 4.63 | −0.33 |
| | Constant | | | 43.19 |
| 88+89 | % Moisture | 20.48 | 23.47 | −2.99 |
| | % Dockage | 13.24 | 13.76 | −0.52 |
| | Test weight | 47.58 | 47.25 | 0.33 |
| | % Protein | 47.78 | 47.39 | 0.39 |
| | Period of storage | 2.04 | 2.24 | −0.20 |
| | Constant | | | −2.02 |

* $S^{-1}(\bar{x}_1-\bar{x}_2) = S^{-1}\bar{x}_1 - S^{-1}\bar{x}_2$

## Discussion

Most countries established grain standard for wheat for economic reasons and for maintaining a high quality of wheat grain which destined for human consumption. The wheat grain standard of Saudi Arabia was built upon some wheat characteristics, which wheat samples may be accepted or rejected. Therefore, wheat producers are forced to produce wheat with specific characteristics.

The quality of wheat grain is relatively high, this probably attributed to the use certified wheat seeds, good cultural practices, and proper storage.

Wheat grain samples characterized by a moderate dockage content. This mainly because broken and shrunken kernels were considered as a part of dockage component. Whereas, they were not considered as a part of dockage in most countries standard (Zeleny 1987).

The most serious threat to wheat after harvest is insect infestations (Cotton *et al.* 1960). Percentage of infested wheat samples were fairly low. They were consisted of 25.8 and 2.1% of the total rejected samples and comprised 1.03 and 0.15% of the total received samples for 1988 and 1989 respectively. Four beetle species were detected in this study. Neither weevils nor moths were found. The low moisture content of wheat grain may probably be the main reason for their absence. Granary weevils, according to Cotton *et. al.* (1960), are unable to breed in grain with moisture content below 9% and the adults soon die in dry grain.

*T. granarium* and *R. dominica*, as primary pests, were expected to be found in wheat grain. Howevr, *T. castaneum* and *Laemophloeus* sp, as secondary pests, were not expected to be found in wheat samples. Sinha (1975) Reed *et al.* (1989) and McGregor (1964) found that the survival and development of secondary insect pests were affected by the amount of dockage. Infested wheat samples were characterized with high percentage of dockage and, thus, may explain the presence of these two insect species in wheat grain.

The moisture and dockage content of infested samples were significantly higher than uninfested samples. Therefore, infested samples may have a special identity compared with free infested grain samples. The discriminate formula which used in this study was promising to determine the identity of the infested wheat grain by using some discriminate variables, and it may be used as a mean to classify the wheat grain samples to infested and free infested.

The moisture content of wheat grain was the most powerful variable in determining the identity of insect infested wheat grain. This probably because the

relative humidity of the studying area is low most of the year. Reduction of moisture content of grain may eliminate the insect infestations or reduce their population density.

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# فحص عينات القمح الواردة إلى المؤسسة العامة للصوامع ومطاحن الدقيق للموسمين ١٩٨٨ و ١٩٨٩م مع التركيز على الاصابة الحشرية

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المملكة العربية السعودية

أجرى هذا البحث في المؤسسة العامة للصوامع ومطاحن الدقيق ومعامل كلية الزراعة جامعة الملك سعود للموسمين ١٩٨٨ و ١٩٨٩م ويهدف هذا البحث إلى فحص عينات القمح الواردة للمؤسسة لتحديد صفات القمح السعودي المقبول ومعرفة الأسباب التي تؤدي إلى رفض قمح بعض المزارعين وفقاً لمواصفات معينة خلال تلك الفترة مع التركيز على عينات القمح المرفوضة بسبب الاصابة بالحشرات ومقارنتها بالقمح السليم.

ومن أهم المواصفات لقبول القمح السعودي خلال فترة الدراسة هي : خلو عينة القمح من الاصابة الحشرية، لا تزيد نسبة الشوائب عن ١٢٪، لا يقل الوزن النوعي عن ٦٧ Kg/HL، لا تقل نسبة البروتين عن ٧ ٪، ولا تزيد نسبة الرمل عن ٠,٥ ٪.

وأظهرت النتائج أن ٩٦ و٩٣٪ من عينات القمح قبلت لمطابقتها للمواصفات للعامين ٨٨ و ٨٩ على التوالي. ويتميز القمح السعودي المقبول بإرتفاع الوزن النوعي (٧٦,٤) وارتفاع المحتوى البروتيني (١,١٤٪) وانخفاض المحتوى الرطوبي (١,٧٪) وانخفاض نسبة الشوائب (١,٥٪).

وقد حصرت أسباب رفض عينات القمح واتضح أن نسبة ارتفاع الشوائب عن الحد المسموح به يشكل ١,٥٦ و ١,٨٧٪ من اجمالي الرفض للعامين ٨٨ و ٨٩ على التوالي بينما تشكل الاصابة الحشرية ٨,٢٥ و ١,٢٪ للعامين على التوالي أما ارتفاع نسبة الرمل عن الحد المسموح فقد كان ٦,١٠ و ٤,٦٪ من اجمالي الرفض.

وأوضحت الدراسة أن من أهم مكونات الشوائب (للعينات المرفوضة بسبب ارتفاع نسبة الشوائب) هي : الشعير (٣٩٪) حبوب قمح مكسور (٥,٢٢٪) حبوب قمح ضامرة (٢,١٩٪) وبذور حشائش (١٥٪).

تم حصر أربعة أنواع من الخنافس في عينات القمح المصاب بالحشرات وكانت أكثرهم أنتشاراً خنفساء الدقيق الصدئية حيث وجدت في ٨,٦٢ و ٥٧٪ من العينات المصابة للعامين على التوالي تليها ثاقبة الحبوب الصغرى حيث وجدت في ٦,٢٥ و ٩,٢٢٪ من العينات المصابة للعامين على التوالي.

واتضح من الدراسة بأن عدد الحشرات لكل كيلو جرام يزداد بزيادة فترة تخزين القمح في صوامع المزارعين وبزيادة نسبة الشوائب. وتتميز عينات القمح المصابة بالحشرات عند مقارنتها بعينات القمح السليمة بارتفاع المحتوى الرطوبي وارتفاع نسبة الشوائب وانخفاض الوزن النوعي.

وأوضحت الدراسة بان المحتوى الرطوبي لحبوب القمح من أهم الصفات للتمييز بين القمح المصاب بالحشرات والسليم ويلي ذلك نسبة الشوائب ثم الوزن النوعي.