EVALUATING THE PERFORMANCE OF LABORATORY MODEL GRAIN CLEANING AND SEPARATING EQUIPMENT FOR GRADING DIFFERENT CLASSES OF GRAIN

by

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B. S., Universidad de Costa Rica, 1983

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1989

Approved by:

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INTRODUCTION

Grain cleaning is one of the most important parts of grain processing. During the harvesting process the grain is separated from the plant. From the first step of grain processing, called threshing, the grain does not come out clean.

After being harvested, the grain still has leaves, stalks, straws, other seeds, immature grain, and broken and shrunken kernels and must be cleaned, regardless of its intended use. The graded quality of the grain depends on its purity and cleanliness and the price depends on the percentage of foreign materials and other undesirable materials.

Cleaning grain increases the length of storage time. Insects find it more difficult to feed and grow in clean grain, and application of fumigants is more effective. Aeration and drying can be done more effectively and economically if the percentage of light, foreign and broken material is low.

For milling purposes, grain cleaning is even more important than in any other activity, since milling requires completely clean grain. Since cleaning the grain costs money, the price of the grain may depend on how clean it is. Therefore, it is necessary to have an easy, fast and reliable method to determine the quantity of light, foreign and broken materials in a given grain sample.

In the United States of America, the standard procedure for grading grain has been to utilize the Carter Day dockage tester. This is a laboratory model grain cleaner which separates the different fractions of the test sample. The same model has been used for several years and has not changed much.

After an intensive review of literature and manufacturers specifications done by Chung et al. (1986), two foreign laboratory grain cleaners were selected for comparison with the Carter Day XT3 dockage tester. The selected models were the Labofix and the N.S.L. They were analyzed to determine their feasibility as grain graders.

The objectives of this research were: 1) to analyze the performance of the three types of grain cleaning and separating equipment, and 2) to suggest modifications of the grain cleaning and separating equipment to improve separation and use for grading grain.

Data on the performance of all three machines have been collected and analyzed from test with five different crops: hard red spring wheat, soft white wheat, grain sorghum, rye, and flaxseed. Two units of each laboratory cleaner were tested. In testing the equipment, two levels of moisture content (11 and 15 percent) and three levels of impurities (5, 10, and 15 percent) in the sample were used. For each individual combination of moisture content and impurity level, three one-kilogram samples were passed through each unit. Each one-kilogram sample was prepared with specific quantities of sound and clean grain, light materials, foreign materials, broken kernels, and powder.

The analysis of the performance was done on an input-output basis. The data obtained from the tests were analyzed statistically in order to determine the differences between efficiency, accuracy, precision, and reproducibility of the three models.

OBJECTIVES

The major objectives of this study were:

1. To analyze the performance of the three types of grain cleaning and separating equipment for grading hard red spring wheat, soft white wheat, grain sorghum, rye, and flaxseed.
2. To suggest design changes for modifying the grain cleaning and separating equipment examined to improve separation so the equipment could be used for grading grain.

LITERATURE REVIEW

For the last 40 years, much research has been conducted on grain cleaning. The objective of this research has been mainly to reach a better understanding of the principles involved in grain cleaning and to discover better grain cleaning methods. Methods and machines have been studied and improved as a result of the findings of this research, and factors affecting the grain cleaning process have been analyzed. Particle size distribution, density, terminal velocity, shape, dimensions, friction coefficient, etc., have been determined for most of the major crops.

General Aspects of Grain Cleaning

The equipment used in grain cleaning takes advantages of differences in physical properties of each of the components in the grain mixture. Cleaning equipment can be classified by the physical property it uses to clean the grain. The principle physical characteristics that are used to clean the grain are: dimension, shape, density, terminal velocity, surface texture, color, resilence, and electrical properties. Branderburg and Park (1977) discussed the principles and practices of seed cleaning by separation with equipment that senses surface texture, color, resilience, and electrical properties of seeds. The machines included texture-sensitive devices, such as the velvet roll and magnetic and friction separators. They described how each device worked and their relevant characteristics and described six different separators and their applications. The velvet roll consists of several pairs of velvet-covered rolls, mounted one pair above another. The rolls of each pair are side by side, in contact along their full length, and inclined horizontally. The rolls rotate in opposite directions so that seeds will be carried upward from the line of contact.

Magnetic separators use differences in surface textures to separate contaminants from the grain. Water is added to the seed mixture, then iron powder is also added; the rough or sticky components pick up the powder, but smooth components do not. The mixture is then passed over a revolving drum having a high intensity magnetic field; the iron-powder-coated materials are attracted to the drum and discharged separately from the smooth, uncoated crop seeds.

The friction separator utilizes the difference in surface texture to separate rough particles from smooth particles. The separation is accomplished by pairs of bars set at an angle across a moving belt. Each pair consist of a friction separator bar followed by a diverter bar. The smooth particles slide diagonally along the face of the separator bar into a collector. The rough particles roll under the separator bar and are intercepted by the diverter bar.

Color separators are electronic devices that separate according to color or dark/light characteristics. The light reflected from the seed to be separated is compared to a preselected background; if the light reflected is different from the background, a signal is generated and the seed is separated.

The resilience separator is a device that uses the difference in bounce properties to separate seeds. It consists of a feeder that drops seeds onto an inclined hard surface and two pans located to catch the good and poor bouncers. Seeds like legumes tend to bounce well, whereas certain grass seed and inert particles do not.

After the seeds have been harvested, the processes or steps required to separate and grade them as high quality, viable seed or for consumption by humans are preconditioning, cleaning, dimensional sizing, separation by specific gravity, surface texture, color or electric charge, separation by shape, chemical treatment, packaging and storing. Wallace et al. (1981) summarized the processing of seed and the basis of the seed cleaning process. They defined seed and grain cleaning as: "a process to remove contaminants, to size-grade for plantability, to upgrade quality through removal of damaged or deteriorated seeds, and to apply chemical seed treatment materials."

The contaminants of grain can be classified as: a) inert materials, b) weed seeds, c) other crop seeds, d) insects, e) deteriorated, damaged or off size kernels of the same seed, f) chaff, g) stick-stems, and h) pods. A single machine cannot separate seeds that differ in all these characteristics. Normally, a different machine must be used to make separations based on each of these characteristics or a single machine, consisting of different parts and mechanisms that utilize different characteristics to separate the grain in the same unit. Size is the most common difference among seeds; a screen machine uses a series of perforated sheet metal or woven wire screens to separate seed of different size. Wallace et al. (1981) explain how the machines clean the grain and what principles are involved in this process. They provide a description of how the machines take advantage of the differences between contaminants and grain and discuss each difference.

Chung et al. (1986) reviewed the state of the art in grain cleaning and published a three-volume report. They collected 244 abstracts from manufacturers and obtained papers from sources such as the Transactions of the American Society of Agricultural Engineers, The Journal of Agricultural Engineering Research, Canadian Agricultural Engineering, Agricultural Engineering, Seed Science and Technology, Filtration and Separation, and Agricultural Mechanization in Asia, Africa and Latin America. Based on cleaning and separation principles, the abstracts were classified into five categories: size and shape, density, surface characteristics, electrical properties, and other. They presented a summary of the literature review discussing the most relevant papers and concluded that more work has to be done in grain cleaning.

In order to design a machine or a process line to clean grain, differentiating characteristics must be chosen. The engineer must know the numerical intervals at which the values of one or more differentiating characteristics are defined. Song (1989) analyzed grain particle separation, reviewed grain cleaning and separation, and collected data on physical properties of various grains. She also discussed the performance of different cleaning devices and factors that affect the cleaning process. A study of the physical properties of the various fractions in corn samples was performed and the possibility of a complete separation of whole kernels was investigated. It is necessary to know the terminal velocity distribution and the particle size distribution of grain and contaminants in order to accomplish good separation. Shape factors and Reynolds Number were correlated with air flotation velocity. "The movement of particles in the air, on the sieve or inside an indented cylinder is not very deterministic, but rather random." Since it is not possible to model the movement of a particle in a separator mathematically, stochastic modeling is a good alternative to represent the experimental data within a certain range of accuracy. Song (1989) used the stochastic theory to simulate the grain cleaning process. This model was evaluated by running samples through an actual cleaner. The stochastic model approximated the experimental data successfully, indicating that the model can be used to predict the separation efficiency.

The Use of Screens in Grain Cleaning

The majority of sizing operations have been performed with perforated surfaces. The difficulty in mathematically modeling the movement of a particle on a screen is the interaction effects which exist between individual particles and the screen surface. Turnquist and Porterfield (1966) used theoretical considerations and dimensional analysis to establish a basic relationship between particles and a single-screen system. They also developed equations for predicting the probability of particle passage using experimental data and the relationship established above. A method was developed for selecting aperture dimensions, screen motions, and areas for a screening system having more than one screen to accomplish a given separation. The results had limited usefulness but did provide a concept which will have applications for other investigations.

Although there is difficulty in mathematically modeling the movement of a particle on a screen some authors have attempted to develop mathematical models and to obtain empirical expressions. English (1974) developed a mathematical treatment of sieving based on the hypothesis that it is the blinding process which is the controlling factor on the mechanics of sieving operations. The validity of the treatment was confirmed by experimental results. It was the first treatment to be based upon the blinding process as a controlling factor and the first to provide a unified approach to both sieving and screening. "Theoretically, the true size of "cut" between the under size and oversize material corresponds to the size of the largest aperture present." It is usually assumed that the materials greater in size than the size of the aperture remain free on the sieve, which implies that no blinding takes place. Some oversize particles can be held in the apertures and not returned to the free material on the sieve. An equation was presented which gave the total amount of material per unit area on the sieve, W, at any time, t. The value for W included the mass of material trapped in the apertures of the sieve plus the free material upon the sieve. Results presented showed that blinding is a real process in sieving and that the theoretical treatment suggested the manner the blinding process occurred. The percentage of blinding materials can be read directly from the size distribution curve if it is assumed that the minimum diameter of a blinding particle is equal to the sieve aperture size. Particles that can be blinding particles have a diameter range which is twice the difference between the average diameter and the minimum diameter. Equations are presented which require the use of a computer, but alternative empirical equations are also presented to encourage the use of the model even when a computer is not available.

The nature of the screen motion plays an important role in the passage of particles and is dependent on the frequency of oscillations, amplitude, screen slope and the linkage angle. The objective of the screen motion is to facilitate the passage of undersize particles through the perforations; however, some of the undersize particles do not pass through. This phenomenon is explained by the tendency of the particles to skip over perforations at high relative velocities. The sliding motion of particles and their distance of travel along the screen are also important factors. Feller and Foux (1975) obtained an empirical expression for the effect of the screen motion variables on particle passage through a perforation. This expression was not dependent on the duration effect, but was based on the screen acceleration with adjustment to the screen amplitude. They used a movie camera to study the behavior of the particles on the screen. Screening is "a random process in which a particle has a certain probability of passing through a perforation in a unit of time." The major parameter that affects kinetic passage conditions is the peak screen acceleration. The percent of material passed through the screen increased with acceleration up to a maximum and then decreased at higher values. No effect of screen inclination and linkage angle were found. At low screen accelerations, particle passage increased with sliding duration. The screen acceleration has a contradictory influence; sometimes it helps to bring particles into alignment with perforations and other times it hinders their entrance into a perforation.

Whenever grain is screened, some particles may enter perforations without being able either to pass through or to exit, thus producing clogging. Clogging gradually decreases the open area of the screen. If the open area is reduced, both sizing accuracy and screen capacity are reduced. Feller (1976) took into account both clogging and passage rate to express the effect of screening duration on particle entrapment in screen perforations. He detailed the methods for determining the clogging rate factors for oversize and undersize particles. The clogging rate factors are defined separately for each size fraction. The clogging rate factors reach a maximum at the range of undersize particles, but this value does not always correspond to the maximum trapping percentage. He explained the relationship between the particle size and the clogging rate. A large fraction of the trapped particles of irregular shape are undersize. Minimizing the trapping of undersize particles is important for an efficient screening process. The maximum clogging rate factor corresponds to a particle size equal to or smaller than the size of the perforations. The clogging rate of undersize particles is more critical than the clogging rate of oversize particles.

One of the factors affecting sizing accuracy is screening duration. The longer the screening duration the better the sizing accuracy; however, there is always a compromise between capacity and accuracy. If screening duration is too long, the capacity is reduced. The rate of passage of particles of a given size through the screen apertures is proportional to the quantity of particles of that size on the screen. Feller and Foux (1976) used screening duration and size distribution as variables in a method to express sizing efficiency. They used sieves with the same aperture shape as in the real process in order to determine the particle size distribution and defined passage rate factors for each size fraction. Sizing efficiency can be determined for any size distribution of the material. The applicability of the method has been proven by experiments for particles of uniform shape. Ratio of particle size to perforation size is a significant factor for the passage rate independently of the particle size.

The separation process depends upon the ability of particles to pass through the apertures of the screen. In evaluating screen performance, both particle passage and clogging of the screen should be considered. Feller (1979) analyzed the screening process by considering both passage and clogging. His objective was to obtain a general expression for the screening process, intended for use in selecting screens, developing and testing new screens and for research purposes. He developed an expression which takes into consideration passage and clogging without relating any particular screening duration or size distribution. This expression used both factors as continuous functions of particle size. At a frequency of 8.83 Hz, clogging was completely eliminated but the passage was very low. This relationship between passage and clogging was stronger for under size particles.

Use of an Indented Cylinder in Grain Processing

The indented cylinder is frequently used for cleaning grain and separating different fractions of grain mixtures. It separates particles on the basis of length differences. The inner surface of the horizontal cylinder has many indentations that lift the grain particles as they pass through the cylinder. Particles are lifted to a certain point, depending on the length of the particle. Long particles are dropped first, and short particles are lifted beyond and dropped into a trough or vibrating tray. Various designs of indents have been tested. The conventional trapezoidal form cell was developed for cleaning long seeds from broken seeds or from spherical weed seeds. The conventional cell has proven to be inadequate for precise length grading. Fouad (1979) studied the effect of cell configuration on length grading of beans. He conducted a systematic study to establish the optimum parameters for the cell design. A new cell was developed with a sharp length separation. Working principles of the separating cell were outlined. The test apparatus consisted of a sheet with indentations mounted on a board that could be rotated to different angles. He explained the different positions that a grain kernel could take in the cell and how it affected the separation efficiency. Different cell types were tested and the new cell was best for the tests conducted. The result applies to a slowly-revolving indented cylinder.

Various designs of indented cylinder have been also tested. Berlage et al. (1983) designed and tested an indented cylinder for separation of seeds. They constructed the cylinder using round-hole perforated metal and discussed the problems with seeds that tended to lodge in the indents. In order to eliminate this problem, they developed a self cleaning device, which completely removed all lodged seeds retaining the selectivity of the indentations. Cylinder speed and slope, feed rate, and collecting tray heights influenced separations.

Other devices similar to the indented cylinder have been tested. Sucher and Pfost (1963) investigated the effects of feed rate, cylinder speed, cylinder slope, screen type, and screen opening on performance of cylindrical graders and efficiency of cylindrical graders in removing rodent contamination from corn. Corn kernel size distribution, both kernel width and kernel thickness, were determined on a weight basis. These cylindrical grader studies were conducted on a number 1 Carter precision grader driven by a 0.25 Kw motor. Cylinder speed was varied by changing motor sheaves and drive belts. The critical speed was calculated at 77.5 rpm. Tests were done in five series. In the first four series, efficiencies were determined based strictly on the separation of corn into two fractions. Overall efficiency was based on recovery of the desired material and rejection of the undesirable material in the feed. Efficiencies for the fifth series of tests were based on the removal of rodent pellets. They reported the corn kernel size distribution, the rodent pellet distributions, and the results from the cylindrical grader tests. It was determined that screen type significantly affected grader efficiency; an indented screen was superior to a flat screen. In all test series, cylinder speed significantly affected grader performance; increasing the feed rate decreased grader efficiency, but increasing cylinder speed increased efficiency. They reported that the result would be limited by the critical speed at which centrifugal force overcomes the force of gravity and particles do not tumble within the cylinder. Rodent pellet removal was not significantly affected by changes in feed rate or cylinder slope within the range tested when a 7.5 mm round hole indented cylinder was used.

Pneumatic Separation of Grains

Chaff and other debris have been separated from shredded grain by using forced air. The separation of grain and impurities is based in differences of terminal velocity. The higher the difference between the terminal velocity of the gain and the impurities, the better the separation. Uhl and Lamp (1961) outlined the methods and results of their research, which determined terminal velocity required for various materials encountered in threshing wheat, rye, oats, corn, and soybeans. They also reported the effect of selected physical characteristics upon the required air velocities for separation. Relationships between air velocity and portions of materials separated were presented for wheat, rye, oats, corn, hay and green-crop mixtures. Graphs were included to demonstrate the relationships between kernel weight, grain bulk density, grain absolute densities and least cross-sectional areas to air velocity required for flotation. The effect of stem length upon air velocity required for flotation was shown, and air velocity required to completely removed the chafflike materials from wheat, rye and soybeans was determined. Grain loss was found to be where the airborne velocity ranges for grain and impurities intercepted. Complete separation of non-grain materials from the grain was possible in soybeans; approximately 80, 94, and 98 percent of oat, wheat, and rye straw, respectively, can be removed without grain loss. By reducing the straw length, a complete separation for straw from wheat and rye is possible. Air separation of corn, corncobs and stover does not appear possible without grain loss.

Winnowing is another method of separating light materials from grain by using forced air. Kashayap and Panya (1966) studied the principles of winnowing and collected experimental data intended to help in the proper design of a winnowing fan in particular, and any other processing equipment based upon pneumatic separation in general. They used a standard test apparatus set up as recommended by the Air Moving and Conditioning Association to obtain steady and uniform air streams. To conduct the experiment, they used paddy grains mixed with six types of chaff; air velocities of 0.9, 2.27, 4.19, 6.78 and 10.46 m/s; heights of 0.84, 1.14, 1.45 and 1.75 m above the platform; and feed angles of 30,45 and 60 degrees. They demonstrated grain-chaff distribution patterns at different air velocities, and found the best air velocity for an efficient winnowing operation. The results were presented in tables showing that there is an optimum air velocity range; below and above this range effectiveness of separation is much reduced.

Pneumatic separation is also used to separate different fractions of a grain mixture. Chattopadhyay et al. (1983) studied a pneumatic separator for various rice fractions. They determined the physical properties of rice bran, germ, and broken kernels. They also developed, tested, and compared two separators. The vertical type separator performed better than the horizontal type. It is impossible to have complete separation because of the dispersion of particle size.

In aerodynamic separation, several factors affect the separation efficiency. The designer must be concerned about shapes, densities, and the range of terminal velocities of the components for each application. Smith and Stroshine (1985) studied the aerodynamic separation of corncobs from corn harvest residue. They found that an air velocity of 10 m/s can separate most of the residues collected during corn harvest. It was also found that complete separation was impractical because some stalk suspension velocities overlapped with those of the corncobs. This problem was caused by stalk pieces with one end node having higher suspension velocities. They used prepared symmetrical corncobs and stalk pieces. It was determined that ideal corncobs and ideal stalks can be separated by air.

MATERIALS AND METHODS

Materials

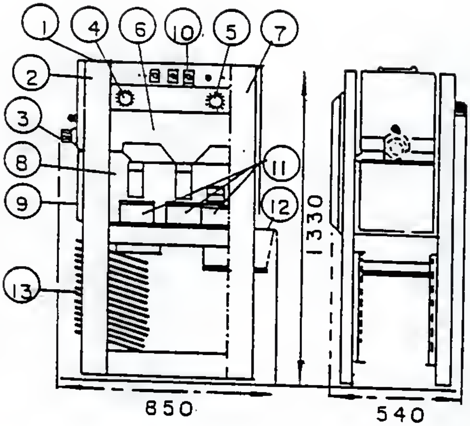
The samples used in this experiment were collected from three sources. Hard red spring wheat, rye, and flaxseed were received from the Department of Cereal Science and Food Technology, North Dakota State University; grain sorghum was collected from the Manhattan Milling Company, Manhattan, Kansas; and soft white wheat was collected from Washington State University, Pullman, Washington.

The equipment tested in this experiment were laboratory models of grain cleaning and separating equipment made in three different countries. The Tripette et Renaud laboratory cleaner-separator model N.S.L. (Figures 1 and 2) was made in France; the Emceka Gompper minicleaner and grader, model Labofix (Figure 3) was made in West Germany; and the Carter Day dockage tester, model XT3 (Figures 4 and 5) was made in the United States of America. Table 1 shows the brand name, model, manufacturer and country where the cleaner was made.

TABLE 1. Equipment Tested in the Project

Brand name	Model	Manufacturer	Country
Mini Cleaner & Grader	Labofix	MCK Maschinenbau	W. German
Laboratory Cleaner-Separator	N.S.L.	Tripette & Renaud	France
Carter-Day Dockage Tester	XT3	Carter-Day	U.S.A.

In addition to the cleaners, the laboratory was equipped with a Motonco moisture meter, two mechanical sieve shakers, balances, stop watches, a Boerner divider, and other minor appliances.



1 Feed hopper
2 Incarporated dehusking
3 Feed output adjustment
4 Front ventilatian adjustment
5 Rear ventilation adjustment
6 Fon spor-box
7 Fon filter
8 Screening spar-box
9 Screen access daor
10 Control panel
11 Waste recovery
12 Sound grain recavery
13 Perforated steel sheet stawage

Figure 1. Schematic Diagram of N.S.L. Laboratory Grain Cleaner. From N.S.L. Laboratory Separator-Cleaner - Instructions for Use. Tripette & Renaud.

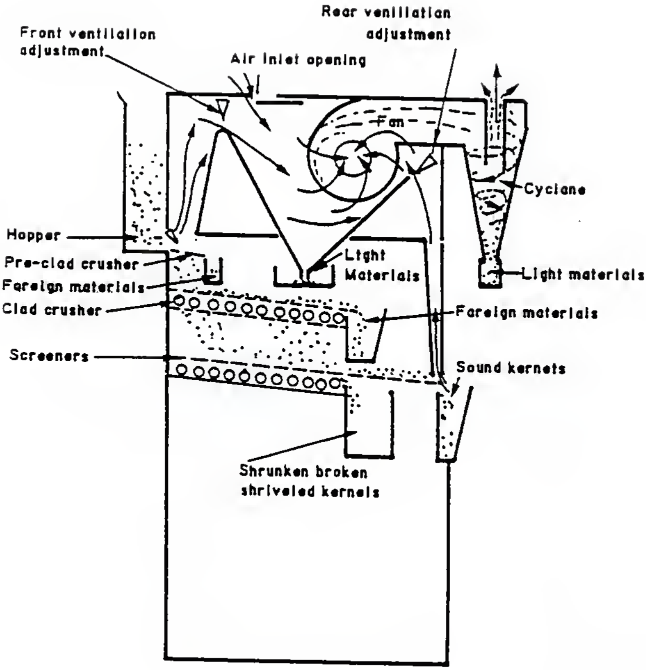


Figure 2. Cross-sectional View of N.S.L. Laboratory Grain Cleaner. From N.S.L. Laboratory Separator-Cleaner - Instructions for Use. Tripette & Renaud.

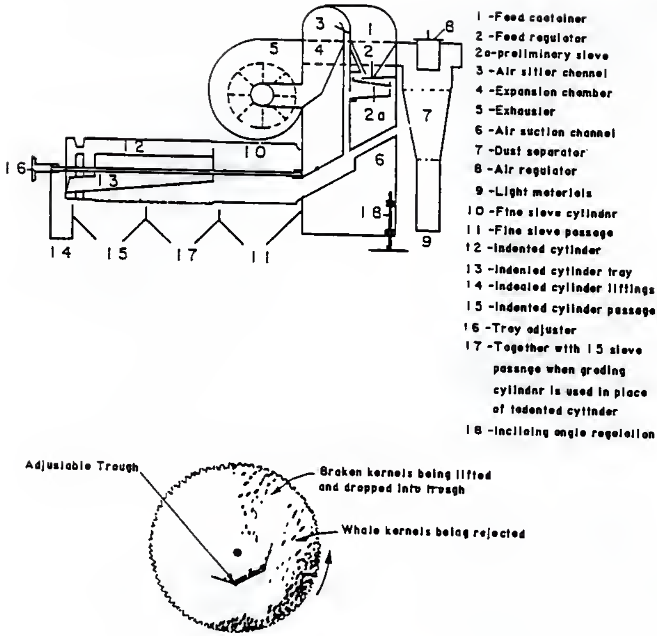
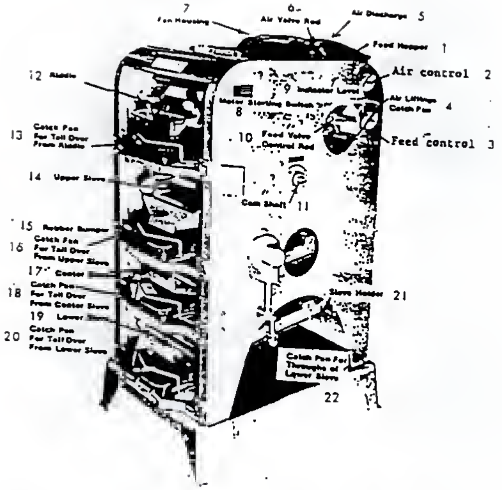


Figure 3. Schematic Diagram of the Labofix Grain Cleaning Unit and Cross-sectional View of Indented Cylinder. From Operating Instructions for Labofix - Operating Plan Pos. 1-52, Drawing No. V492. MCK Maschinenbau.



1. Feed hopper
2. Air control
3. Feed coetrol
4. Air liftlegs catch pan
5. Air discharge
6. Air valve rod
7. Fan housings
8. Motor slarting swilch
9. Indicator level
10. Feed valve control rod
11. Cam shaft
12. Riddle
13. Catch pan for tail over from riddle
14. Upper sleve
15. Rubber bumper
16. Catch pan for tail over from apper sleve
17. Center sieve
18. Catch pan for tail over from ceeter sleve
19. Lower sleve
20. Catch pan for tail over from lower sleve
21. Sleve holder
22. Catch pan for lhoreoghs of lower sleve

Figure 4. Schematic Diagram of CD-XT3 Dockage Tester. From Dockage Tester Style XT3 After October 1987 - Instruction Manual 179-6. Carter-Day.

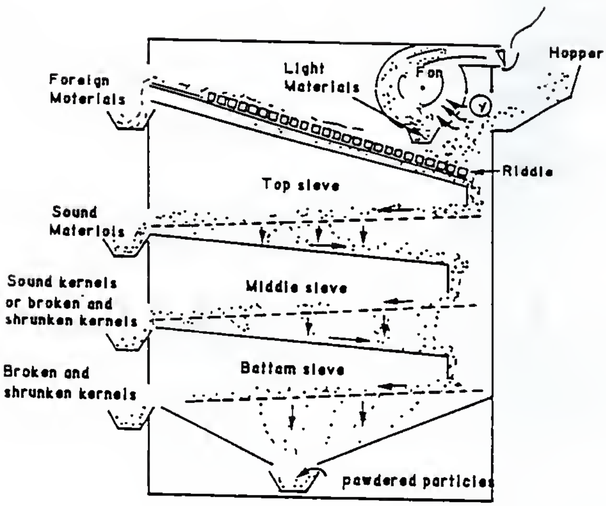


Figure 5. Sectional View of CD-XT3 Dockage Tester. From Dockage Tester Style XT3 After October 1987 - Instruction Manual 179-6. Carter-Day.

Methods

The experiment started with an analysis of the principles of separation of each model in order to adjust proper parameters for grain cleaning.

A preliminary cleaning test was performed to set up the air and feed controls. Control settings were based on the operational manuals provided by the manufacturer or on the results of this preliminary test. For the XT3, the controls were set according to the United States standards. Control settings for each machine and grain type are presented in Tables 2 to 5. In order to evaluate the cleaning operation of each model objectively, the setting of aspirators, feeders and screens were based on the following assumptions:

A. Feed control: adjusted so the 1 Kg grain sample passed through all sieves in three minutes or less.

B. Air control: adjusted so that sound kernels were not removed from the grain samples.

C. Scalping sieve: must retain only particles larger than the whole kernels of the grain being tested.

D. The first screen: must retain all sound kernels of the sample. Where the indented cylinder was used, the size was adjusted so sound kernels of the grain sample would not end up in the broken kernel fraction.

The sieve used in the XT3 complied with the United States standard specifications. The dimension of scalpers, screens, and indented cylinders are compared in Table 6 for the three cleaning units.

The three models tested separated the sample into different fractions. The fractions recovered in the trays were designated as S1B, S2B, S3B, S4B, S5B, or S6B, depending on what part of the machine function removed them. These fractions are defined later.

The impurities of grain consisted of six components: broken kernels, shrunken kernels, shriveled kernels, powdered particles, light materials and foreign materials.

TABLE 2. Screen Sizes and Feed and Air Control Settings for the Three Laboratory Grain Cleaners when Testing Wheat

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 6 A.C.: 4		Double Aspiration F.C.:2 A.C.:6 (Front), AIO:4	6 (Rear)	Single Aspiration F.C.: 1.2 A.C.: 4.5 A.T.: 3 Incl.: Horizontal	
Scalping Sieves	Riddle #2 (white, spring & winter wheat)	5.0 x 5.0	Pre-clod Crusher	RH 9.0	Pre-sieve	LH 4.0 x 22
			Clod Crusher	LH 3.50 x 20		
1st Screening			Screener	LH 1.75 x 20	Fine Sieve Cylinder	LH 1.75 x 20
2nd Screening	Middle Sieve #2	RH 1.98			Indented Cylinder	4.5
					Grading Cylinder	
3rd Screening	Bottom Sieve #2	RH 1.98				

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slotted perforated sieve
RH = Round perforated sieve

TABLE 3. Screen Sizes and Feed and Air Control Settings for the Three Laboratory Grain Cleaners when Testing Grain Sorghum

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 6 A.C.: 1		Double Aspiration F.C.: 2 A.C.: 5 (Front), AIO: 4	10 (Rear)	Single Aspiration F.C.: 1.1 A.C.: 5 A.T.: 2 Incl.: Horizontal	
Scalping Sieves	Riddle #6	3.57 x 3.57	Pre-clod Crusher	RH 9.0	Pre-sieve	RH 5.5
			Clod Crusher	LH 4.50 x 20		
1st Screening	Top Sieve #6	Tri 1.984	Screener	LH 2.0 x 20	Fine Sieve Cylinder	LH 1.75 x 20
2nd Screening					Indented Cylinder	3.0
					Grading Cylinder	
3rd Screening	Bottom Sieve #1	RH 0.991				

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slotted perforated sieve
RH = Round perforated sieve
Tri. = Triangular perforated sieve

TABLE 4. Screen Sizes and Feed and Air Control Settings for the Three Laboratory Grain Cleaners when Testing Rye

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 6 A.C.: 4		Double Aspiration F.C.: 2 A.C.: 6 (Front), AIO: 4	6 (Rear)	Single Aspiration F.C.: 1.2 A.C.: 4.5 A.T.: 3 Incl.: Horizontal	
Scalping Sieves	Riddle #2	5.63 x 5.63	Pre-clod Crusher	RH 9.0	Pre-sieve	LH 3.75 x 22
			Clod Crusher	LH 3.5 x 20		
1st Screening			Screener	LH 1.75 x 20	Fine Sieve Cylinder	LH 1.75 x 20
2nd Screening	Middle Sieve #2	RH 1.98			Indented Cylinder	4.5
					Grading Cylinder	
3rd Screening	Bottom Sieve #2	RH 1.98				

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slotted perforated sieve
RH = Round perforated sieve

TABLE 5. Screen Sizes and Feed and Air Control Settings for the Three Laboratory Grain Cleaners when Testing Flaxseed

	CD XT-3		N.S.L.		Labofix	
	Specification	Dimension (mm)	Specification	Dimension (mm)	Specification	Dimension (mm)
Feed & Air Control	Single Aspiration F.C.: 4 A.C.: $3\frac{1}{2}$		Double Aspiration F.C.: 2 A.C.: 3 (Front), AIO: 4	3 (Rear)	Single Aspiration F.C.: 0.25 A.C.: 2.5 A.T.: 4 Incl.: Horizontal	
Scalping Sieves	Riddle #000	5.0 x 5.0	Pre-clod Crusher	RH 9.0	Pre-sieve	RH 4.75
			Clod Crusher	LH 2.5 x 20		
1st Screening	Top Sieve #4	LH 1.63 x 9.53	Screener	RH 1.50	Fine Sieve Cylinder	RH 2.25
2nd Screening	Middle Sieve #2	RH 1.98			Indented Cylinder	3.0
					Grading Cylinder	
3rd Screening	Bottom Sieve #7	RH 1.778				

AIO = Air inlet opening
F.C. = Feed control
A.C. = Air control
A.T. = Angle of trough
Incl. = Inclination

LH = Slotted perforated sieve
RH = Round perforated sieve

TABLE 6. Comparison of Scalpers and Screens Used in the Cleaning Units for the Grains Tested (all dimensions are in mm)

Screening Stages	CD XT3		N.S.L.		Labofix	
	Riddle		Clod-crusher		Pre-sieve	
	No. 00	3.75				
Scalper	No. 1	4.33				
Wheat	No. 2	5.00	L 3.50 x 20	L 4.5 x 20	L 4.0	R 5.0
Sorghum	No. 6	3.57 x 19.05	L 3.50 x 20	L 4.5 x 25	L 5.5	
Rye	No. 25	5.63	L 5.0 x 30	R 4.5	L 3.75	R 4.75
Flax	No. 000	5.00	L 4.5 x 20	L 5.0 x 30	R 3.5	
	Top Screener Sieve		Fine Sieve			
1st Screening						
Wheat	#4	1.64 x 9.52	L 1.75 x 20		L 1.75	
Sorghum	#8	2.26 (Δ)	2.26 (Δ)			
Sorghum	#6	1.98 (Δ)	1.98 (Δ)	R 3.0	L 1.9 x 20	L 1.75
Rye	#4	1.64 x 9.52	L 1.75 x 20		L 1.75	
Flax	#4	1.64 x 9.52	R 1.5		R 2.25	
	Middle Sieve				Indented cylinder or grading cylinder	
2nd Screening						
Wheat	#2	1.98			4.5	10.0
Sorghum					2.2	
Rye	#2	1.98			4.5	11.0
Flax	#2	1.98			3.0	6.0
	Bottom Sieve					
3rd Screening						
Wheat	#2	1.98				
Sorghum	#1	0.99				
Rye	#2	1.98				
Flax	#7	1.78				

L and R before the dimension refer to a slotted perforated sieve and a round hole perforated sieve, respectively.

Sieve No. 4 was not used for wheat in the XT3 cleaner (Table 6). In order to determine how much of the broken and shrunken kernels remained in the sound kernel fraction of the XT3, approximately 240 g of the sound kernel fraction were sieved through a slotted hole sieve (1.64 mm wide and 9.52 mm long) using an official mechanical sieve shaker. The fraction of sound kernels had been reduced using the Boerner divider.

To compare how much of the broken and shrunken kernel fraction of the two European machines were sound kernels according to the U.S. standards, these fractions were sieved in the mechanical shaker.

The efficiency of separation was based on the calculation of removal efficiency of the impurities in the test samples.

$$\text{Removal efficiency} = \eta\text{imp} = \frac{\text{(IMP)out}}{\text{(IMP)in}}$$

Where, (IMP)in = total mass of impurities in test samples before separation

(IMP)out = total mass of impurities removed during separation

The samples with three levels of impurities, (IMP)in, were prepared by adding 50, 100 and 150 gr of impurities to sound kernels fractions of 950, 900 and 850 gr, respectively. Preparation of the impurities is discussed later. Table 7 shows the test data sheet used to record the data. The total impurities after separation were calculated as follows.

Total mass of impurities removed during separation:

XT3 (IMP)out = S1B + S2B + S4B + S5B + S6B

N.S.L. (IMP)out = S1B + S2B + S3B + S5B + S6B

Labofix (IMP)out = S1B + S2B + S3B + (S4B)* + S6B

* (S4B) only applicable to the grading cylinder of Labofix.

TABLE 7. Test Data Sheet

So	C		M		I	

No.________

Operator:________________ Machine:________________

Date:________________

Test Sample: 1 Kg Type of Grains:____________

M.C. level:__________ Feed Control:____________

Impurity level:________ Air Control:____________

No. of Replicates / Fractions*		1	2	3
S1B				
S2B				
S3B				
S4B				
S5B				
S6B				
Mechanical Sieve	SM			
	BM			
Testing time[1]				
Feed control[2]				
Air control[3]				
Sieve Cleaning[4]				
Comment				

*Fractions

	CD XT-3	N.S.L.	Labofix**
S1B	LM	LM#1	LM
S2B	FM	FM#1	FM
S3B	SM	FM#2	BM#2
S4B	BM#1 or SM	SM	SM (BM)
S5B	BM#2	BM	BM#1 (BM)
S6B	PM	LM#2	- (SM)

**Indented cylinder installed

( ): Grading cylinder installed

LM: light materials
FM: foreign materials
SM: sound kernels
BM: broken kernels
PM: powdered kernels

[1] Testing time was measured in minutes used to clean the grain sample of 1 kg.

[2] Feed control with weighted factors: excellent = 3; good = 2; fair = 1.

[3] Air control with weighted factors: excellent = 3; good = 2; fair = 1.

[4] Sieve cleaning with weighted factors: excellent = 3; good = 2; fair = 1.

Where, S1B = mass of light materials removed by the aspirator

S2B = mass of foreign materials removed by the riddle or pre-sieve

S3B = mass of foreign materials (N.S.L.) or mass of broken and shrunken kernels (Labofix)

S4B = mass of broken and shriveled kernels, and mass of sound kernels when the top sieve was not used

S5B = mass of broken kernels and powdered particles

S6B = mass of powdered particles (XT3), mass of light materials (N.S.L.) or mass of broken kernels (Labofix) and mass of sound kernels when the grader was used

Sound kernels fraction were designated as S3B for XT3, S4B for N.S.L. and S5B for Labofix. In the case of flaxseed cleaning by the XT3, sound kernels were collected at the recovery tray of S4B, whereas foreign materials were removed at S2B and S3B.

For analysis of the performance of the three machines, the total mass of impurities were divided into three main fractions: light materials (LM), foreign materials (FM), and broken, shrunken, or shriveled kernels and powdered particles (BSSP). The removal efficiency was calculated using the following formulas:

$$\eta_l = (LM)out / (LM)in$$

$$\eta_f = (FM)out / (FM)in$$

$$\eta_b = (BSSP)out / (BSSP)in$$

For the XT3: (LM)out = S1B

(FM)out = S2B

(BSSP)out = S4B + S5B + S6B

For the N.S.L.: (LM)out = S1B + S6B

(FM)out = S2B + S3B

(BSSP)out = S5B

For the Labofix: (LM)out = S1B

(FM)out = S2B

(BSSP)out = S3B + (S4B) + S6B

Where, η_l = removal efficiency of light materials

η_f = removal efficiency of foreign materials

η_b = removal efficiency of broken, shrunken, or shriveled kernels and powdered particles

(LM)out = mass of light materials removed by separation

(FM)out = mass of foreign materials removed by separation

(BSSP)out = mass of broken, shrunken, shriveled kernels or powdered particles removed by separation

Accuracy of separation was evaluated by calculating the removal efficiency. The precision was evaluated by calculating the coefficient of variance. Reproducibility was evaluated by the differences between the two units of each model and the differences between the three replicates. Applicability of each model was investigated by the evaluation of removal efficiencies. The evaluation of ease of operation of each model was based on an assessment of feed and air control, sieve cleaning, and changing parts. The noise level of each model was also measured, and the length of time for every test was recorded. The noise level was measured one foot from the cleaner at a height of four feet. The N.S.L. and the Labofix measurements were made in the front of the units; however, the noise level measurement of the XT3 was at the side of the unit, where the trays are located. These locations correspond to the place where the operator would stand while operating the cleaners.

Preparation of Test Samples

In order to determine the removal efficiencies of each model, impurity fractions were defined as follows: (1) light materials were all matter separated by an aspirator system; (2) foreign materials were all matter removed by a scalper; (3) broken kernels were all broken and shrunken kernels removed either by cleaning equipment or hand picking; (4) powdered particles were all matter passing through the middle or bottom sieve of the XT3; and (5) sound kernels were whole kernels or kernels with more than 3/4 of the kernel without any impurity.

The definition of various fractions of broken and shrunken kernels prepared in the laboratory are shown in Table 8.

Table 9 shows the percentage of each impurity added to the samples. The three levels of impurities, as shown in Table 9, were each tested with three replicates.

In order to determine the effect of moisture content on the performance of each model, two levels of moisture content were selected: 11 and 15 percent (WB). The desired moisture level was obtained by adding water to the sound kernel fraction. After water was added to the samples, they were stored for a minimum of four days in a cold chamber for moisture equilibration.

TABLE 8. Definition of Various Fractions of Broken and Shrunken Kernels Prepared in the Lab

Fractions / Grains	BM#1	BM#2	BM#3	PM
Wheat (HRS, White)	broken cross-sectioned	#4	a* + $\frac{\#2}{\#2}$	#2
Grain	$\frac{\#8}{\#6}$	$\frac{\#6}{\#1}$	#1	-
Rye	broken kernels cross-sectioned	#4	a* + $\frac{\#2}{\#2}$	#2
Flax	$\frac{\text{Riddle 000}}{\#4}$	$\frac{\#2}{\#7}$	#7	-

Note: Sieve numbers shown are those of Carter-Day Dockage tester.

#2 = Broken pieces passing through #2

$\frac{\#8}{\#6}$ = Broken pieces passing through #8 but remaining on #6

a* = Tyler sieves used (2.00 mm/1.65 mm). BM#3 portion is those kernels remaining on the 1.65 mm sieve.

The amount of water necessary to increase the moisture content to 11 and 15 percent was calculated by the following equation:

$$\Delta = P\left[\frac{MC_2 - MC_1}{100 - MC_2}\right]$$

Where, Δ = amount of water to be added (Kg)

P = sample weight (Kg)

MC_1 = initial moisture content (%)

MC_2 = desired moisture content (%)

The samples with 11 percent moisture content were prepared by adding the required amount

TABLE 9. Three Impurity Levels of Test Samples

Low Level

Test Samples / Fractions *	Wheat HRS White	Sorghum	Rye	Flax
LM	0.2	0.3	0.2	1.8
FM	0.4	0.1	0.4	0.2
BM#1	2.3	2.0	0.4	0.6
BM#2	1.0	1.5	3.2	0.6
BM#3	1.0	1.1	0.4	1.8
PM	0.1	-	0.4	-
Total	5%			

Medium Level

Test Samples / Fractions *	Wheat HRS White	Sorghum	Rye	Flax
LM	0.4	0.6	0.4	3.6
FM	0.8	0.2	0.8	0.4
BM#1	4.6	4.0	0.8	1.2
BM#2	2.0	3.0	6.4	1.2
BM#3	2.0	2.2	0.8	3.6
PM	0.2	-	0.8	-
Total	10%			

High Level

Test Samples / Fractions *	Wheat HRS White	Sorghum	Rye	Flax
LM	0.6	0.9	0.6	5.4
FM	1.2	0.3	1.2	0.6
BM#1	6.9	6.0	1.2	1.8
BM#2	3.0	4.5	9.6	1.8
BM#3	3.0	3.3	1.2	5.4
PM	0.3	-	1.2	-
Total	15%			

* LM = Light Materials
FM = Foreign Materials
BM#1 = Broken Kernels, splits or 2/3 intact kernels
BM#2 = Broken and shrunken kernels or 1/3 intact kernels
BM#3 = Fine broken kernels
PM = Powdered particles

of water to the sound kernels; the samples with 15 percent moisture content were prepared by adding the required amount of water to the sound and broken kernels fractions.

Experimental Design

The experimental design was developed to evaluated the accuracy, precision, reproducibility, ease of operation, and applicability of each individual model to each individual crop.

The significant parameters to be investigated in this experiment were as follows:

1. Two levels of moisture content: 11 and 15 percent (W.B.). These two levels were selected to determine the effects of moisture content on the performance of each model.
2. Three levels of impurities: 5, 10, and 15 percent. These three levels were selected to determine the effect of the impurity level on the performance of each model.
3. Efficiency, accuracy and reproducibility were calculated by doing a material balance of impurities on an input-output basis.

In addition, general operational factor were to be determined by the evaluation of noise level during cleaning operation, the amount of dust formed, and the ease of cleaning and changing of screens.

Figures 6 and 7 show the experimental procedures for the cleaning test of the five crops.

In this experiment the independent variables were model, unit, crop, moisture content, and impurity level. The dependent variables were efficiency, accuracy, reproducibility, applicability and testing time.

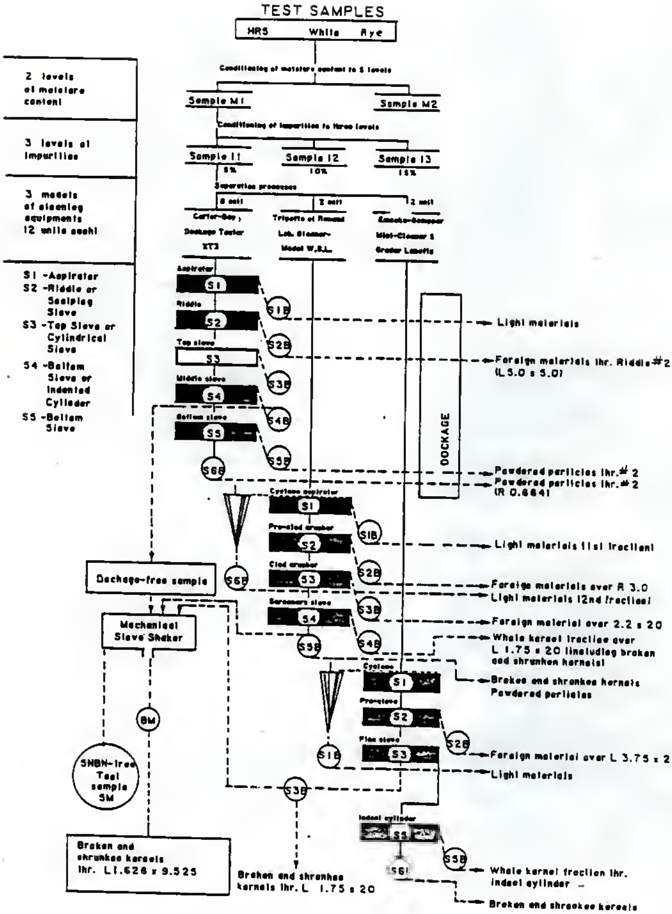


Figure 6. Experimental Procedures for Cleaning Tests of HRS and White Wheat and Rye

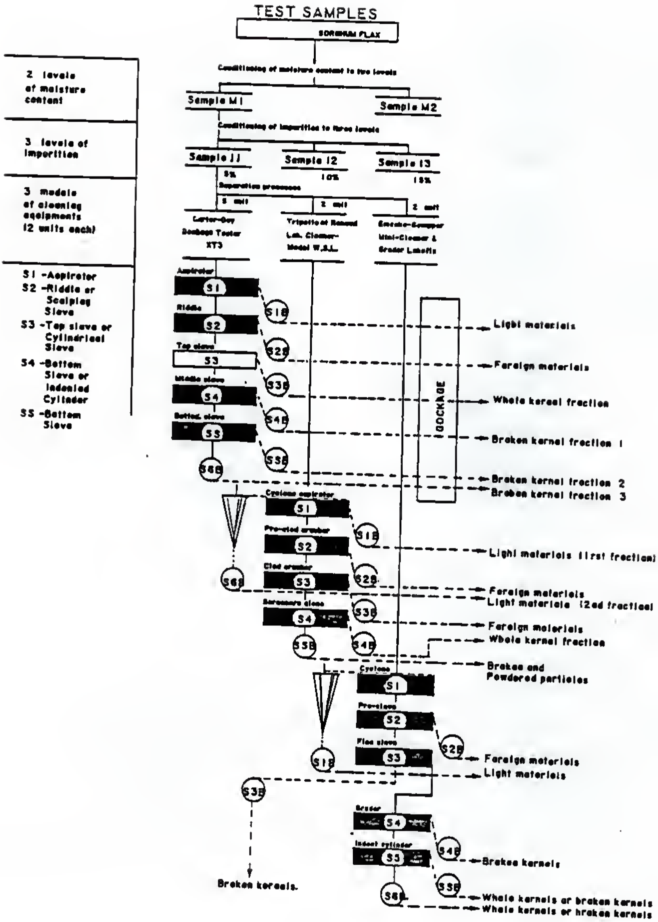


Figure 7. Experimental Procedures for Cleaning Tests of Grain Sorghum and Flaxseed

Statistical Analysis

This is a factorial experiment. The response y, efficiency, is observed at all factor-level combinations of the independent variables, which are crop, unit/model, moisture content, and impurity level. For each factor-level combination, two units and three replicates were tested.

For each crop, the statistical model can be written as follows:

$$y_{ijklm} = \mu + \beta_j + \gamma_{k(j)} + \rho_l + \theta_m + \beta\rho_{jl} + \beta\theta_{jm}$$

$$+ \theta\gamma_{mk(j)} + \rho\gamma_{lk(j)} + \rho\theta_{lm} + \beta\rho\theta_{jlm} + \theta\rho\gamma_{mlk(j)} + \varepsilon_{ijklm}$$

Where $y_{(ijklm)}$: efficiency

i:	1,..., 36
j:	1, 2, 3
k:	1, 2
l:	1, 2
m:	1, 2, 3
μ:	overall mean
β_j:	effect of model
$\gamma_{k(j)}$:	effect of unit/model
ρ_l:	effect of moisture content
θ_m:	effect of impurity level
$\beta\rho_{jl}$:	interaction between model and moisture content
$\beta\theta_{jm}$:	interaction between model and impurity level
$\gamma\theta_{k(j)m}$:	interaction between unit/model and impurity level
$\gamma\rho_{k(j)l}$:	interaction between unit/model and moisture content

$\rho\theta_{lm}$: interaction between moisture content and impurity level

$\beta\rho\theta_{jlm}$: interaction between model, moisture content, and impurity level

$\gamma\rho\theta_{k(j)lm}$: interaction between unit/model, moisture content, and impurity level

ε_{ijklm}: random error

An analysis of variance was performed to test the significance of each factor. A regression analysis was also performed to test whether a linear association existed between the efficiency and the significant factors.

RESULTS

Hard Red Spring Wheat

Means and Standard Deviations

The means and standard deviation of the weight of the six fractions from the three models of cleaning machines at impurity levels of 5, 10, and 15 percent are presented in Tables A-1 to A-6 in the Appendix. Although these means and standard deviations were calculated, the analysis of the results of this experiment were based on the removal efficiencies of overall impurities, light materials, foreign materials and broken kernels. All data collected were processed using the Statistical Analysis System (SAS).

Removal Efficiency

Tables A-31A through A-36F in the Appendix summarize the calculated values of overall removal efficiencies of three replicates at impurity levels of 5, 10, and 15 percent for the three models of cleaning machines tested. The values in these tables are also presented graphically in Figures 8 and 9.

The average overall removal efficiency of the three cleaning machines for hard red spring wheat was found to be in the following order:

Labofix > N.S.L. > XT3

The ranges of overall removal efficiencies for the three models tested were: from 14.2 to 18.3 percent for the XT3, from 27.1 to 56.9 percent for the N.S.L., and from 82.0 to 97.1 percent for the Labofix.

There was a significant difference between the overall removal efficiencies of the three machines.

The removal efficiencies of light materials, foreign materials, and broken kernels are presented in Tables A-31B through A-36B in the Appendix. These values are also shown in figures

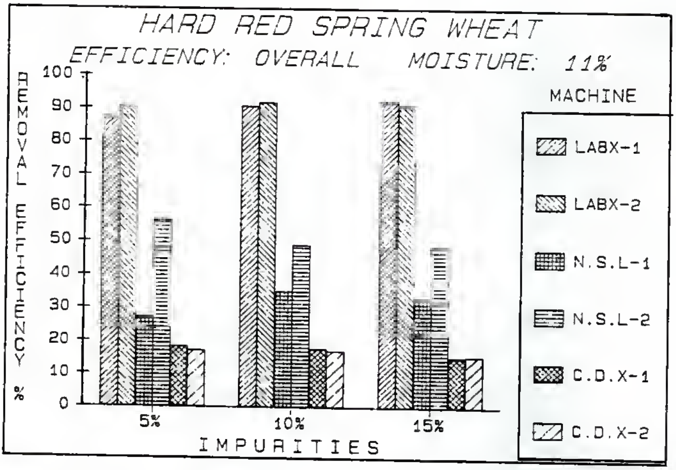


Figure 8. Overall Removal Efficiency by Two Units Each of the Labofix, N.S.L., and CD-XT3 Models for Hard Red Spring Wheat at 11 Percent Moisture

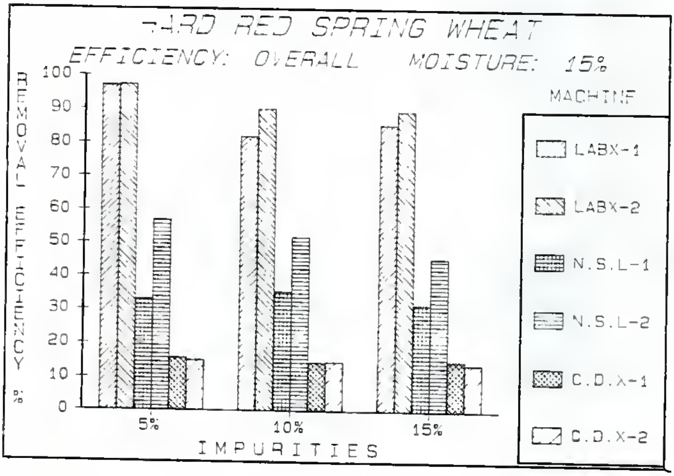


Figure 9. Overall Removal Efficiency by Two Units Each of the Labofix, N.S.L., and CD-XT3 Models for Hard Red Spring Wheat at 15 Percent Moisture

A-1 through A-6 in the Appendix. The removal efficiency of each component was found to be as follows:

η_l for light materials: N.S.L. > Labofix > XT3

η_f for foreign materials: XT3 > Labofix > N.S.L.

η_b for broken kernels: Labofix > N.S.L. > XT3

Effect of Moisture Content

The effect of moisture content on the overall removal efficiency was negligible for the N.S.L. units, but the efficiency was slightly higher at 11 percent moisture content than at 15 percent moisture content with the XT3 units. This was confirmed by the analysis of variance and the regression analysis. Table A-61 in the Appendix shows that the effect of moisture content was significant for unit 2 of the XT3. For all other units of the Labofix and N.S.L. models, the effect of moisture content was not significant.

The moisture content produced different effects on the removal efficiencies of light, foreign and broken materials. The effect of moisture content also differed depending on the machine. The removal efficiency of light materials for the XT3 was higher at 15 percent moisture content than at 11 percent moisture content. This was confirmed by the regression analysis. The effect was the opposite for the N.S.L. and Labofix units; for these models, the removal efficiency of light materials was higher at 11 percent moisture content than 15 percent moisture content, but this result was not statistically significant. The effect of the moisture content was also stronger on the XT3 than on the Labofix and N.S.L. What was said above about the effect of moisture content on the removal efficiency of light materials was confirmed again by the statistical analysis. In this case, both units of the XT3 were affected significantly by the moisture content. The results of the analysis of variance for the moisture content effect on the removal efficiency of light materials for hard red spring wheat are presented in Table A-65. Results from the regression analysis are presented in Table A-94.

The moisture content had considerable effect on the removal efficiencies of foreign materials with the XT3 and N.S.L. units, but no effect with the Labofix units. This was confirmed by the statistical analysis on the effect of moisture content on the removal efficiency of foreign materials. As shown in Table A-69, effect of moisture content was significant for units 2 of the N.S.L. and XT3. Table A-95 shows the regression analysis.

The moisture content had no effect on the removal efficiency of broken kernels for the N.S.L. and Labofix units, but did have a considerable effect on the XT3. The removal efficiency of broken kernels with the XT3 was lower at 15 percent moisture content than at 11 percent moisture content. Table A-96 shows a negative slope. Both units of the XT3 the moisture content had a significant effect on the removal efficiency of broken kernels (Table A-23).

Effect of Impurity Level

The impurity level had a considerable effect on the overall removal efficiency, which decreased as the impurity level increased with all three cleaning machines. Units 2 of Labofix, N.S.L. and XT3 showed a significant effect of the impurity level on the overall removal efficiency for hard red spring wheat (Table A-62). The effect of impurity level on units 1 of the three models was less than in units 2. Although the effect of impurity level was not statistically significant on all unit 1s, we can see the minor effect by looking at Figures 8 and 9. The regression analysis showed that only for the XT3 is there a linear association between overall removal efficiency and impurity level. The slope is negative (Table A-93).

The impurity level strongly effected the removal efficiency of light materials for the XT3; the efficiency increased as the impurity level increased (Figure A-1 and Table A-94 in the appendix). The statistical analysis indicated that this effect of the impurity level on the removal efficiency of light materials of the XT3 was significant as shown in Table A-66. The impurity level had no effect on the removal efficiency of light materials for the Labofix and N.S.L. models.

It must be noted that the removal efficiencies of light materials presented in this report are modified efficiencies. The excess of weight recovered in the light material fraction over the input weight was added to the broken kernels fraction. This was done in order to obtain more realistic results. Without the modification, light material removal efficiencies were, in some cases, higher than 100 percent because broken kernels and powder recovered in the light material fraction were counted as light material. With modified efficiencies, 100 percent efficiency does not indicate an acceptable level. This modified efficiency is also inconvenient, since mixing the light materials, broken kernels, and powder in the same pan do not allow determination of the exact amount of light materials present in the sample. Tahles A-97 through A-111 present the raw data of light and hroken materials recovered by the cleaner.

The impurity level had no effect on the removal efficiency of foreign materials of any of the three models (Table A-70).

The impurity level significantly affected the removal efficiency of hroken kernels for the N.S.L. and XT3 models (Table A-74). The removal efficiency of broken kernels decreased as the impurity level increased. The slope of the linear association was significant for the XT3 but not for the N.S.L. (Tahle A-96). The effect of the impurity level on the removal efficiency of broken kernels for Labofix was not significant (Table A-77 and Figures A-5 and A-6).

Analysis of Precision

Table 10 presents the results on average coefficient of variance. When working with hard red spring wheat, the average coefficient of variance was found to be: 4.85 percent for the Labofix, 9.32 percent for the XT3, and 11.5 percent for the N.S.L. Based on the coefficient of variance, the precision was found to he:

Lahofix > XT3 > N.S.L.

A coefficient of variance of 4.85 percent indicated that the Lahofix has a high precision.

TABLE 10. Average Coefficient of Variance for Overall Removal Efficiency with HRS Wheat

Unit	Labofix	N.S.L.	CD-XT3
1	6.32%	11.70%	10.97%
2	3.39%	11.41%	7.68%
Average	4.86	11.55	9.33

The XT3 has an acceptable precision. It must be noted that the coefficient of variance of 9.32 percent is the average of 10.97 percent for unit 1 and 7.68 percent for unit 2. In Table A-82 the coefficient of variance for overall efficiency is shown; a coefficient of variance larger than 10 percent is an indication of low precision.

Both N.S.L. units had a coefficient of variance larger than 10 percent. A coefficient of variance of 11.55 percent indicates that the precision of the N.S.L. is not good enough to be used as an standard for grain grading.

Tables A-83 through A-85 give the coefficient of variance for the removal efficiency of light and foreign materials and broken kernels.

Since the removal efficiency of light materials was modified for Labofix and N.S.L. the coefficient of variance of removal efficiency of light materials was zero for both models.

Unit 1 of the XT3 had a coefficient of variance of 22.25 percent and unit 2 of the XT3 had a coefficient of variance of 20.48 percent. Therefore the precision of the XT3 when removing light materials would not meet the requirements.

The precision was the worst for all three models when removing foreign materials and was found to be in the following order:

XT3 > Labofix > N.S.L.

The coefficient of variance for the removal efficiency of foreign materials was 10.2 percent for the XT3, 13.79 percent for the Labofix, and 46.65 percent for the N.S.L. Only the coefficient of variance for the XT3 was almost to 10 percent, which indicated that the XT3 was more precise than the Labofix and N.S.L. models when removing foreign materials.

Table A-85 shows the coefficient of variance for removal efficiency of broken materials. The Labofix had the highest precision among the models when removing broken kernels. The coefficients of variance were 5.2 percent for the Labofix, 12.78 percent for the N.S.L. and 44.7 percent for the XT3. The precision when removing broken kernels was found to be in the following order:

Labofix > N.S.L. > XT3

This clearly demonstrated that one of the best features of the Labofix model was the high precision when removing broken kernels.

Analysis of Reproducibility

The results from unit 1 and from unit 2 of the Labofix model were significantly different and the unit effect on the overall removal efficiency was significant.

The unit effect was also significant for units 1 and 2 of the N.S.L., while the unit effect was not significant in the overall removal efficiency of the XT3 model.

Table A-63 presents the statistical analysis for units effect on the overall removal efficiency.

The XT3 is more convenient than the Labofix and N.S.L. models for hard red spring wheat because of its higher reproducibility.

Table A-67 shows the statistical analysis for the units effect on the removal efficiency of light materials.

Since the removal efficiency of light materials was modified, tbere was no difference between the results of unit 1 and unit 2 for tbe N.S.L. and Labofix models. Tbe XT3 results reflected a significant difference between unit 1 and unit 2.

The statistical analysis for units effect on the removal efficiency of foreign materials is shown in Table A-71. There was no effect of tbe units on tbe removal efficiency of foreign materials for any of the three models.

Table A-75 presents the statistical analysis for units effect on the removal efficiency of broken kernels. As for the overall removal efficiency, the units effect was significant for the Labofix and N.S.L. The units did not affect the removal efficiency of broken kernels of tbe XT3.

Reproducibility was bigh for all three models wben the analysis was done over the replicates effect. Tablc A-64 shows tbe statistical analysis of the effect of replicates on the overall removal efficiency. There was no effect of the replicates on the overall removal efficiency or on the removal efficiency of foreign materials for any of the three models. This can be seen in Table A-72.

The replicates effect was significant for tbe removal efficiency of ligbt materials of unit 2 of the XT3, but did not affect any of the otber units (Table A-68).

The replicates effect was significant for the removal efficiency of broken kernels of unit 2 of Labofix and unit 1 of XT3. By examining Table A-76 we can determine that the N.S.L. was the only one that tbe replicates effect was not significant in both units.

Separation by the Mechanical Shaker

About one-fourtb of the sound kernel fraction from tbe test for the XT3 was further separated by the designated sieve (1.64 mm x 9.52 mm) on a mecbanical shaker approved by FGIS. The results of broken/sound kernel fraction separation are presented in Table A-86.

Approximately 4.27 percent of tbe sound kernels fraction were broken kernels. This indicates that using a sieve #4 on the XT3 would improve the removal efficiency of broken kernels and the overall removal efficiency.

Table 11 presents the projected increase of overall removal efficiency at different moisture content and impurity levels for the XT3.

TABLE 11. Projected Increase of Overall Removal Efficiency at Different Moisture Contents and Impurity Levels for the XT3 with HRS Wheat

	Impurity level		
Moisture content	5%	10%	15%
11%	42.0%	42.2%	39.7%
15%	42.9%	42.8%	42.7%

Removal efficiency of broken kernels could be improved from 5.84 percent up to 53.09 percent and the overall removal efficiency could be improved from 15.88 up to 57.66 percent using the designated sieve.

Analysis of the Official Grading by KSGIS

In order to compare the test results with the official grading, one duplicate set of test samples of each impurity level and moisture content for hard red spring wheat was prepared. The six samples were sent to the Kansas State Grain Inspection Service (KSGIS), Topeka, Kansas, for official grading. The results from the two test procedures are compared in Figures 10 and 11. These figures show the relationship between the analysis done by the KSGIS and the results from this experiment. The x-axis data is that obtained from the analysis done by the KSGIS and the y-axis is the results from this experiment.

For hard red spring wheat, the Labofix was the only model which removed more than was reported as impurity materials by the KSGIS, as indicated by the line with a slope larger than 1.

The N.S.L. removed fewer impurities than those reported by the KSGIS analysis.

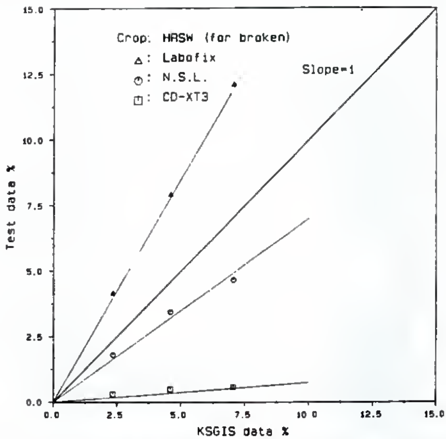


Figure 10. Comparison Between Results from KSGIS and Test Data on Broken Materials Removed

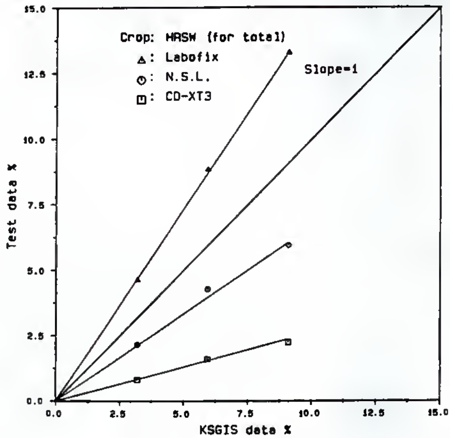


Figure 11. Comparison Between Results from KSGIS and Test Data on Total Impurities Removed

The XT3 had the smallest slope, which indicated that it removed much fewer impurities than those reported by the KSGIS analysis. This was because the shrunken and broken kernels reported by the KSGIS is the fraction removed using the mechanical shaker with a sieve having holes of 1.64 mm wide and 9.52 mm long.

The shrunken, broken and foreign materials are determined by KSGIS after the sample has been cleaned of dockage. The KSGIS reports dockage, foreign materials, and shrunken and broken kernels, while this experiment reports only dockage. If the designated screen #4 had been used, the line slope in Figures 10 and 11 would have been closer to 1.

Analysis of Applicability

The analysis of applicability can be based on all the factors analyzed so far which includes removal efficiencies, precision, reproducibility, effect of moisture content, effect of impurity level, plus ease of operation, testing time, noise level and strengths and weaknesses of each model, which are discussed later.

From this point of view, Labofix has the highest applicability. Labofix has the highest removal efficiency and the highest precision.

The Labofix presented fewer operational problems. N.S.L. had problems removing the foreign materials, testing times were different, the feeder did not work correctly, and the light materials container did not have enough capacity. The XT3 blows away a lot of light materials, the riddle carried some powder and removed big sound kernels as foreign materials, and it does not have a sieve cleaning system.

Because the largest fraction in the grain sample is the broken kernels fraction and because Labofix has as its main feature the removal of broken kernels, Labofix has the highest overall removal efficiency. Although N.S.L. has a high removal efficiency of light materials and XT3 has a high efficiency removing foreign materials, the Labofix does a good job removing these two fractions. This makes the Labofix the most applicable model for hard red spring wheat.

White Wheat

Means And Standard Deviations

The results of means and standard deviations of different fractions resulting from the three models at impurity levels of 5, 10, and 15 percent are presented in Tahles A-7 through A-12 in the Appendix. The analysis of results was hased on the removal efficiency of overall impurities, light materials, foreign materials, and broken kernels. All the collected data were processed by using the statistical analysis system (SAS).

Removal Efficiency

Tables A-37A through A-42A in the Appendix summarize the average overall removal efficiencies of three replicates at impurity levels of 5, 10, and 15 percent for the three models of cleaning machines tested. Values in these tables are also presented graphically in Figures 12 and 13.

The average overall removal efficiency of the three cleaning machines for soft white wheat was found to be in the following order:

Lahofix > N.S.L. > XT3

The ranges of overall efficiencies for the three machines tested were from 13.6 to 20.5 percent for XT3, from 31 to 66 percent for N.S.L., and from 66 to 92 percent for Labofix. The statistical analysis showed that the differences hetween the three models was significant.

The removal efficiencies of light materials, foreign materials, and broken kernels are presented in Tables A-37B through A-42B, and are shown in Figures A-7 through A-12. The removal efficiency of each component of impurities was found to be as follows:

η_l for light materials: N.S.L. > Lahofix > XT3

η_f for foreign materials: N.S.L. > XT3 > Labofix

η_b for Broken kernels: Lahofix > N.S.L. > XT3

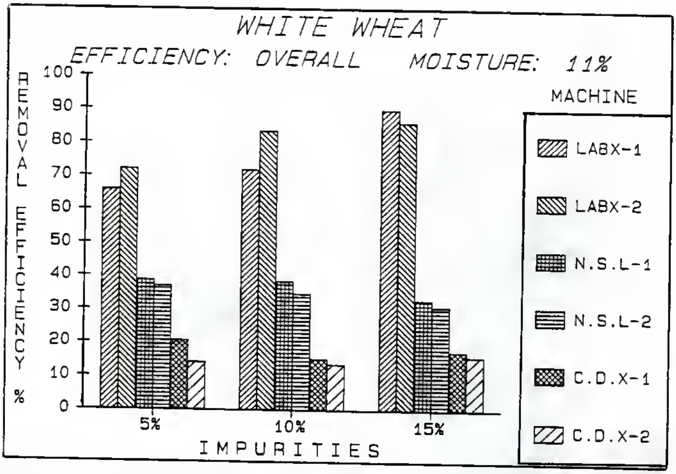


Figure 12. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L., and CD-XT3 Models for White Wheat at 11 Percent Moisture

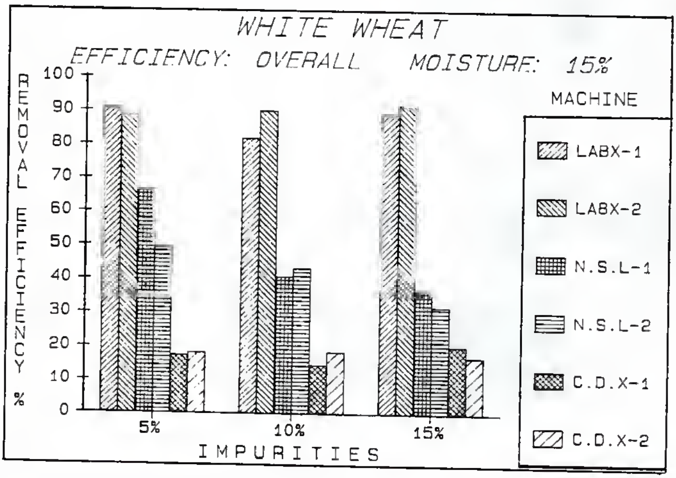


Figure 13. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L., and CD-XT3 Models for White Wheat at 15 Percent Moisture

Effect of Moisture Content

The moisture content had a considerable effect on the overall removal efficiency of all three machines tested; the overall removal efficiency was higher at 15 percent moisture content than at 11 percent moisture content. This result was confirmed by variance and regression statistical analysis. In Table A-61, the effect of moisture content was significant for both units of Labofix, for unit 1 of N.S.L., and for unit 2 of XT3. In Table A-93, the slope is positive.

The analysis performed before the removal efficiency of light materials and broken kernels were modified indicated that the moisture content had a considerable effect on the removal efficiency of light materials and broken kernels of the XT3 and Labofix units. These efficiencies were higher at 15 percent moisture content than at 11 percent moisture content, which was confirmed by the statistical analysis. Table A-65 shows that the effect of moisture content on the removal efficiencies of light materials was significant for unit 2 of XT3.

Moisture content had a strong effect on the removal efficiency of foreign materials for the N.S.L. units. Removal efficiency of foreign materials was higher at 15 percent moisture content than at 11 percent moisture content. This result was confirmed by the regression analysis. The effect of the moisture content on the removal efficiency of foreign materials of the XT3 and the Labofix was the opposite. Removal efficiency of foreign materials was higher at 11 percent moisture content than at 15 percent moisture content, but the regression analysis did not show a significant relationship.

The statistical significance of these results can be checked Tables A-69 and A-95, where it can be seen that for both units of N.S.L., the effect of the moisture content was significant and had a positive slope. It must be noted that moisture content had no effect on the removal efficiency of foreign materials of XT3 and was significant only for unit 2 of Labofix.

Removal efficiency of broken kernels was higher at 15 percent moisture content than at 11 percent moisture content for Labofix. The difference was statistically significant with a positive slope, as can be seen in Tables A-73 and A-96. The effect of moisture content on the removal efficiency of broken kernels was not significant for the XT3 and N.S.L.

Effect of the Impurity Level

The effect of the impurity level on tbe overall removal efficiency of the XT3 units was negligible. In Tables A-62 and A-93, it can be observed that for tbe XT3 model the effect of the impurity level was not significant. For the N.S.L. units, the overall removal efficiency decreased as the impurity level increased, wbich was confirmed by tbe variance and regression statistical analysis.

Impurity level bad the opposite effect on the overall removal efficiency of the Labofix. The overall removal efficiency for Labofix increased from 79 percent at the 5 percent impurity level to 89 percent at the 15 percent impurity level. This result was confirmed by tbe regression analysis. Since the removal efficiency of light materials for Labofix and N.S.L. was modified, the effect of impurity level cannot be determined. Impurity level affected the removal efficiency of light materials of unit 2 of XT3 (Table A-66), but there was not a linear association (Table A-94).

The impurity level affected the removal efficiency of foreign materials of unit 2 of Labofix, unit 1 of N.S.L., and unit 1 of XT3. In this case, the removal efficiency of foreign materials decreased as the impurity level decreased. The linear association was significant only for the N.S.L. model.

Impurity level did not affect the removal efficiency of broken kernels of the N.S.L. and XT3, but did have a significant effect on the removal efficiency of broken kernels for the Labofix. Removal efficiency of broken kernels for the Labofix model increased as tbe impurity level increased (Table A-96).

Analysis of Precision

Table 12 presents the results for average coefficient of variance.

When working with white wheat, the average coefficient of variance was 10.48 percent for the Labofix, 19.85 percent for the XT3, and 25.05 percent for the N.S.L. Based on the coefficient of variance, the precision was as follows:

Labofix > XT3 > N.S.L.

TABLE 12. Average Coefficient of Variance for Overall Removal Efficiency with White Wheat

Unit	Labofix	N.S.L.	CD-XT3
1	12.78%	27.72%	19.42%
2	8.19%	22.37%	20.28%
Average	10.49	25.05	19.85

Labofix had the smallest coefficient of variance. Although it was larger than 10 percent, tests indicated that the Labofix had the highest precision among the three models.

The precision of the XT3 and N.S.L. when working with white wheat was not acceptable. Both coefficients of variance were much larger than 10 percent. Tables A-82 through A-85 show the coefficient of variance of the three models when working with white wheat.

The coefficient of variance for removal efficiencies of light materials, foreign materials, and broken kernels of all the three models were larger than 10 percent.

All three models reflected lower precision when working with white wheat than when working with hard red spring wheat, except the coefficient of variance for removal efficiency of light materials for Labofix and N.S.L. This was because these efficiencies has been modified.

Analysis of Reproducibility

Tables A-63, A-67, A-71, and A-75 present the statistical analysis for units effect on the overall removal efficiency and on the removal efficiency of light materials, foreign materials, and broken kernels. The units effect was significant on overall removal efficiency of the Labofix and N.S.L., but was not significant on the overall removal efficiency of the XT3. Removal efficiency of light materials was not affected by the units effect for any of the three models.

The units effect on removal efficiency for foreign materials was significant only for the N.S.L. The effect of units on the removal efficiency of broken kernels was significant only for the Lahofix.

The results from the XT3 when working with white wheat were affected less by the units effect than the results from the Labofix and N.S.L. The XT3 had a higher reproducihility than the Lahofix and N.S.L.

Tables A-64, A-68, A-72, and A-76 show the replicates effect on the removal efficiencies for overall, light and foreign materials, and for hroken kernels. Replicates had no effect on the overall removal efficiency, the removal efficiency of light materials, foreign materials or broken kernels, which indicated high reproducibility for each unit for all models.

Separation by the Mechanical Shaker

The results of broken/sound kernel fractions separated hy the mechanical shaker using the designated sieve (1.64 mm x 9.52 mm) are presented in Table A-87. Since approximately 3.28 percent of the sound kernel fraction were broken kernels, removal efficiency of broken kernels can he improved by using sieve No 4 on the XT3. Tahle 13 presents the projected increase at different moisture contents and impurity levels for the XT3.

TABLE 13. Projected Increase of Overall Removal Efficiency at Different Moisture Contents and Impurity Levels for the CD-XT3 with White Wheat

	Impurity level		
Moisture content	5%	10%	15%
11%	28.7%	31.5%	33.5%
15%	36.4%	33.3%	31.3%

Using sieve #4, the removal efficiency of broken kernels could be improved from 7.57 to 44.58 percent and the overall removal efficiency can be improved from 16.94 to 48.47 percent.

Analysis of the Official Grading by KSGIS

Six samples of white wheat were sent to the Kansas State Grain Inspection Service (KSGIS). The results from both test procedures are compared in Figures 14 and 15.

The Labofix is the only model with a slope larger than 1 for white wheat, which indicates that the Labofix is the only model which removed more than was reported as impurities by the KSGIS.

The N.S.L. removed fewer impurities than those reported by the KSGIS analysis. As reflected by the smallest slope, the XT3 removed much fewer impurities than reported by the KSGIS analysis.

Analysis of Applicability

Taking into account such factors as removal efficiency, precision, reproducibility, ease of operation, and operational problems, the Labofix is the most applicable model for white wheat and has the highest overall removal efficiency and the highest precision. Although the XT3 had the highest reproducibility, the high precision of the Labofix and its high efficiency made it more applicable than the XT3. The applicability of the XT3 could be improved by using screen #4.

The N.S.L.'s low precision and low reproducibility indicated that it was not suitable for grading white wheat.

Grain Sorghum

Means and Standard Deviations

The results of means and standard deviations of different fractions resulting from the three models of cleaning machines at each impurity level and moisture content are presented in Tables A-13 through A-18 in the Appendix.

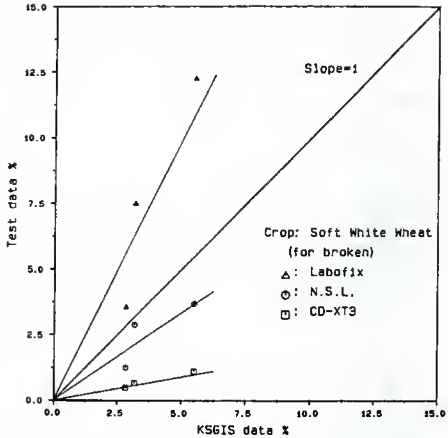


Figure 14. Comparison Between Results from KSGIS and Test Data on Broken Materials Removed

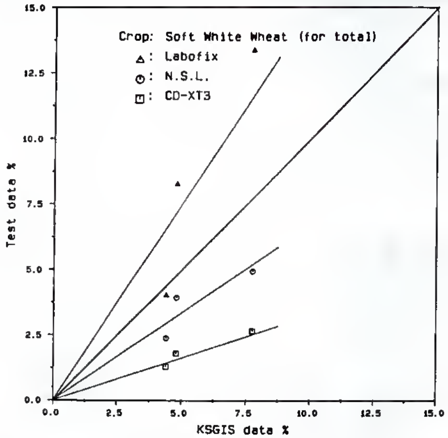


Figure 15. Comparison Between Results from KSGIS and Test Data on Total Impurities Removed

Removal Efficiencies

Tables A-43A through A-48A summarize the calculated values of average overall removal efficiencies of three replicates at impurity levels of 5, 10, and 15 percent for the three models of cleaning machines tested. The values in these tables are presented graphically in Figures 16 and 17.

The average overall removal efficiency of the three cleaning machines for grain sorghum was found to be in the following order:

Labofix > XT3 > N.S.L.

The ranges of average overall removal efficiency for the three machines tested were: from 76.07 to 87.52 percent for the Labofix; from 57.87 to 71.51 percent for the XT3; and from 53.93 to 62.82 percent for the N.S.L.

The removal efficiency of light materials, foreign materials and broken kernels are presented in Tables A-43B through A-48B. These values are also shown in Figures A-13 through A-18 in the Appendix. The removal efficiency of each component of impurities was found to be as follows:

η_l for light materials: Labofix = N.S.L. > XT3

η_f for foreign materials: XT3 = Labofix > N.S.L.

η_b for broken kernels: XT3 > Labofix > N.S.L.

Effect of Moisture Content

The effect of moisture content on the overall removal efficiency was negligible for the XT3 units, but the efficiency was higher at 11 percent moisture content than at 15 percent moisture content with the N.S.L. and Labofix units. These results were confirmed by the statistical analysis. In Table A-61 the effect of moisture content was significant for both units of the N.S.L. and for unit 1 of the Labofix. In Table A-93, the slope for the Labofix and N.S.L. was negative.

The moisture content was found to affect the removal efficiency of light materials. For the N.S.L. and Labofix units, the removal efficiency of light materials was greater at 11 percent moisture content than at 15 percent moisture content. The statistical analysis in Tables A-65 and A-94 do not

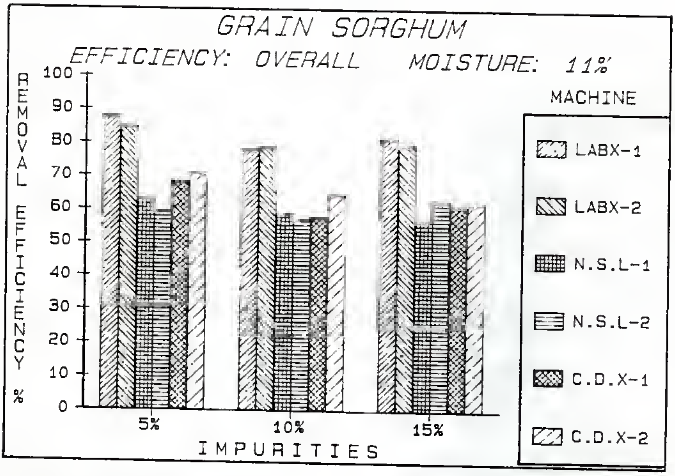


Figure 16. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L., and CD-XT3 Models for Grain Sorghum at 11 Percent Moisture

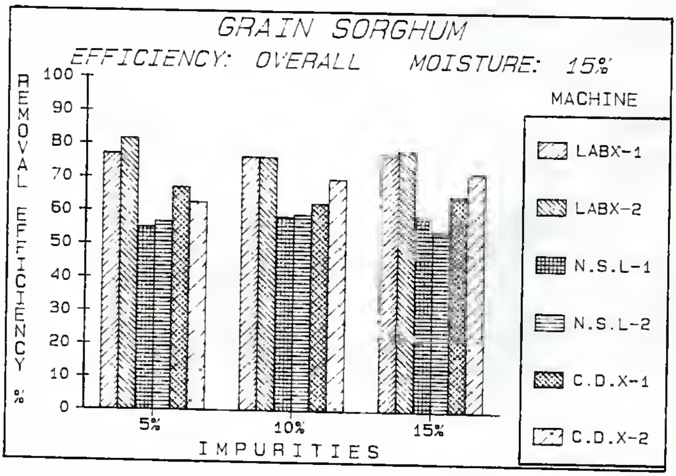


Figure 17. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L., and CD-XT3 Models for Grain Sorghum at 15 Percent Moisture

show this effect because the removal efficiency of light materials of Labofix and N.S.L. have been modified.

The XT3 units were unable to remove any light materials; consequently, the XT3 removal efficiency of light materials was zero, as shown in Figures A-13 and A-14. Also for this reason, Tables A-65 and A-94 reflect no effect of the moisture content on the removal efficiency of light materials for the XT3.

Moisture content had a significant effect on the removal efficiency of foreign materials for the N.S.L. units. The removal efficiency of foreign materials was greater at 15 percent moisture content than at 11 percent moisture content (Table A-95). The effect of the moisture content on the removal efficiency of foreign materials was the same on the Labofix units as on the N.S.L., but it was the opposite on the XT3 units.

The effect of moisture content on the removal efficiency of broken kernels with the N.S.L. and Labofix units was considerable. The removal efficiency of broken kernels was greater at 11 percent moisture content than at 15 percent moisture content when working with the N.S.L. and the Labofix units (Table A-96). Moisture content had no effect on the removal efficiency of broken materials when working with the XT3 units. These results were confirmed by the statistical analysis. Table A-73 shows that the effect of the moisture content was significant for both units of the N.S.L. and for unit 1 of the Labofix model. Table A-96 shows a negative slope for the Labofix and N.S.L. models.

Effect of the Impurity Level

The impurity level had no effect on the overall removal efficiency of the N.S.L. and XT3 models. No relationship between the impurity level and the overall removal efficiency was found in either of these machines. The impurity level significantly affected the overall removal efficiency of the Labofix model. This was confirmed by the statistical analysis. In Tables A-62 and A-93, it can be seen that the impurity level had no effect on the overall removal efficiency for both units of the N.S.L. and that the slope for the Labofix was significant.

No relation was found between the impurity level and the removal efficiency of light materials and foreign materials. These results are confirmed at Tables A-66, A-70, A-94 and A-95, where the effect of the impurity level was not significant. The regression analysis showed a negative slope for the linear relationship between removal efficiency of broken kernels of the Labofix (Table A-96).

Analysis of Precision

Table 14 presents the results on average coefficient of variance.

TABLE 14. Average Coefficient of Variance for Overall Removal Efficiency with Grain Sorghum

Unit	Labofix	N.S.L.	CD-XT3
1	5.64%	4.85%	6.07%
2	4.43%	5.40%	7.23%
Average	5.04	5.13	6.65

When working with grain sorghum, the average coefficient of variance has been found to be 5.04 percent for the Labofix, 5.13 percent for the N.S.L., and 6.65 percent for the XT3 model. Consequently, precision was found to be in the following order:

Labofix > N.S.L. > XT3

All the three models have a high precision. In Table 14 none of the values for coefficient of variance has a value larger than 10 percent, which indicates that the precision of all three models when working with grain sorghum is acceptable.

It must be noted that the precision of the three models was acceptable for the overall removal efficiency. However, there were serious problems when evaluating the removal efficiency of foreign materials, especially in the case of the N.S.L., which had an unacceptable coefficient of variance larger than 100 percent.

Removal efficiency of broken kernels for the three models showed good precision. The coefficient of variance for the removal efficiency of broken kernels was 5.83 percent for the Labofix, 5.97 percent for the N.S.L., and 6.83 percent for the XT3. The precision for the removal efficiency of broken kernels was as follows:

Labofix > N.S.L. > XT3

Analysis of Reproducibility

The units effect was not significant on the overall removal efficiency of the Labofix and N.S.L. For the XT3, the units effect on the overall removal efficiency was significant (Table A-63).

For the removal efficiency of light materials (Table A-67) the units effect was not significant for any of the three models. It must be noted that the removal efficiency of light materials was modified.

Table A-71 shows the statistical analysis for the units effect on the removal efficiency of foreign materials. The effect of units was not significant for any of the three models.

The units effect on the removal efficiency of broken materials was significant only for the XT3. This can be confirmed in Table A-75.

The replicates effect was not significant for any of the three models or for any of the three efficiencies. Tables A-64, A-68, A-72, and A-76 present the statistical analysis for the replicates effect.

From this analysis, we can conclude that reproducibility of the Labofix and N.S.L. was slightly better than that of the XT3.

Analysis of the Official Grading by the KSGIS

The results from the KSGIS analysis and the results from this experiment are compared in Figures 18 and 19. Lines for the three models have a slope close to 1, indicating that both analyses were similar for grain sorghum.

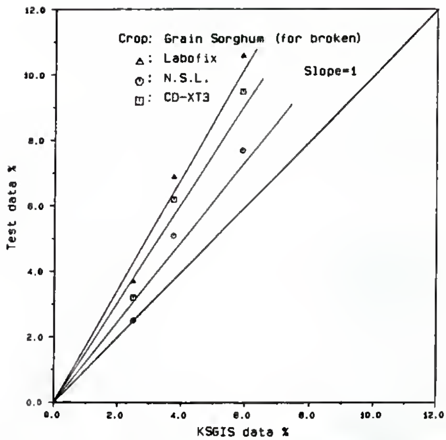


Figure 18. Comparison Between Results from KSGIS and Test Data on Broken Materials Removed

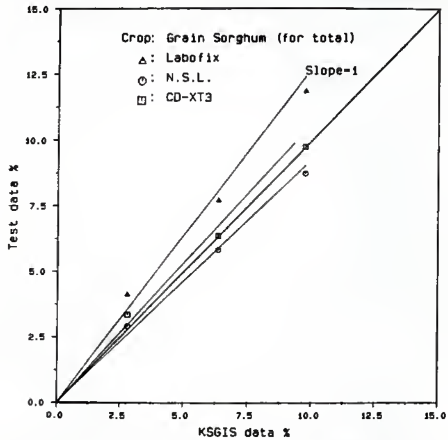


Figure 19. Comparison Between Results from KSGIS and Test Data on Total Impurities Removed

Results from the Labofix, N.S.L. and from the XT3 in this experiment reported more broken kernels removed than the results from the KSGIS.

Analysis of Applicability

Labofix has the highest overall removal efficiency and the highest precision among the three models. The units effect on the removal efficiency of the Labofix was not significant, which indicated that the Labofix has a high reproducibility. All of these factors, plus the fact that Labofix presented fewer operational problems than the N.S.L. and the XT3 would suggest it to be the most applicable model for grading grain sorghum.

Rye

Means and Standard Deviations

The results of means and standard deviations of different fractions resulting from the three models of cleaning machines at impurity levels of 5, 10, and 15 percent are presented in Tables A-19 through A-24 in the Appendix.

Removal Efficiency

Tables A-49A through A-54A in the Appendix summarize the calculated values of overall removal efficiency of three replicates at impurity levels of 5, 10, and 15 percent, and moisture contents of 11 and 15 percent for the three models of cleaning machines tested. The values in these tables are also presented graphically in Figures 20 and 21.

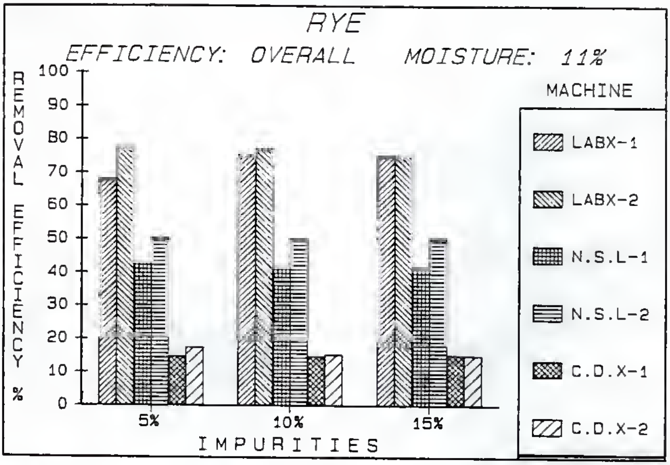


Figure 20. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L., and CD-XT3 Models for Rye at 11 Percent Moisture

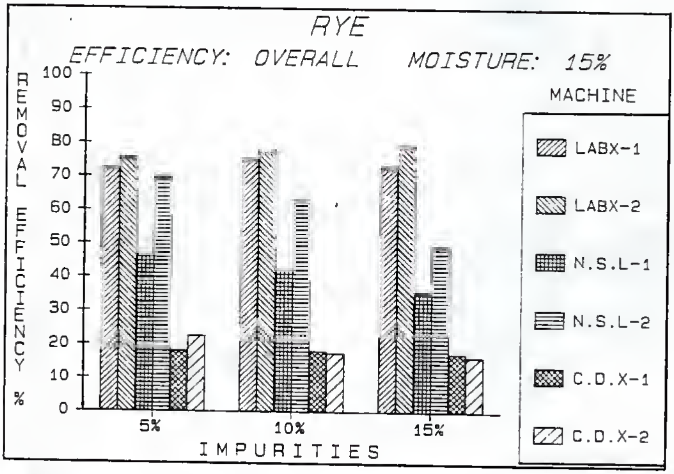


Figure 21. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L., and CD-XT3 Models for Rye at 15 Percent Moisture

The ranking in average overall removal efficiency of the three cleaning units was as follows:

Labofix > N.S.L. > XT3

Ranges of average overall removal efficiencies for the three models tested were: from 65.4 to 80.5 percent for the Labofix; from 33.5 to 81.6 percent for the N.S.L.; and from 14.2 to 24.4 percent for the XT3. Statistical analysis showed that the difference between the three models were significant.

Average overall efficiencies of the Labofix, N.S.L., and XT3 units were 79.02, 69.33, and 22.47 percent, respectively. The removal efficiency of light materials, foreign materials and brokens are presented in Figures A-19 through A-14 and Tables A-49 through A-54B in the Appendix. The average removal efficiency of each component was found to be:

η_l for light materials: N.S.L. > Labofix > XT3

η_f for foreign materials: XT3 > Labofix > N.S.L.

η_b for broken Kernels: Labofix > N.S.L. > XT3

Effect of Moisture Content

For overall removal efficiency, the statistical analysis (Tables A-61 A-93 in the Appendix) indicated that the effect of moisture content was not significant for the Labofix and N.S.L., but was significant for the XT3 with a positive linear relationship. The effect of moisture content on the removal efficiency of light materials was significant for the XT3 (Tables A-65 and A-94). There was no difference for the removal efficiency of light materials for the Labofix and N.S.L. after the removal efficiency was adjusted.

For the removal efficiency of foreign materials, the effect of moisture content was statistically significant for all the three models and units, except unit 2 of the Labofix (Tables A-69 and A-95). For the removal efficiency of broken kernels the effect of the moisture content was not statistically significant for any of the three models and units, except for unit 2 of the XT3.

Effect of the Impurity Level

Impurity level did not significantly affect the overall removal efficiency for the three models and units, except unit 2 of XT3. Table A-93 shows a negative slope for the XT3 model. Removal efficiency of light materials was not affected by the impurity level. The effect of the impurity level was not significant for the removal efficiency of foreign materials for the three models and units except for unit 2 of the XT3 (Table A-95). The effect of the impurity level on the removal efficiency of broken kernels was not significant for the models and units except for unit 1 of the N.S.L. and unit 2 of the XT3. Table A-96 showed negative linear relationship for the N.S.L. and XT3 models.

Analysis of Precision

Table 15 presents the results for average coefficient of variance.

TABLE 15. Average Coefficient of Variance for Overall Removal Efficiency with Rye

Unit	Labofix	N.S.L.	CD-XT3
1	5.92%	11.20%	9.79%
2	2.69%	21.72%	15.34%
Average	4.31	16.46	12.57

When working with rye, the average coefficient of variance was 4.31 percent for the Labofix; 12.57 percent for the XT3; and 16.46 percent for the N.S.L. Based on the coefficient of variance, precision was found to be:

Labofix > XT3 > N.S.L.

The coefficients of variance of the XT3 and N.S.L. models were larger that 10 percent so their precision was not acceptable. Table A-82 shows the coefficient of variance for the overall removal efficiency and Tables A-83 through A-85 show the coefficient of variance for the removal efficiency of light materials, foreign materials, and broken kernels, respectively. The coefficient of variance for the removal efficiency of light materials, foreign materials and broken kernels were much larger that the coefficient of variance for the overall removal efficiency.

Analysis of Reproducibility

The units effect was significant for the overall removal efficiency of the Labofix and N.S.L., but there was no difference in the overall efficiency between the XT3 units.

The effect of units was significant for the removal efficiency of light materials of the XT3. The units effect was significant for the removal efficiency of foreign materials of the N.S.L. and XT3 but was not significant for the Labofix.

The units effect was significant for the removal efficiency of broken kernels of the Labofix and the N.S.L., but was not significant for the removal efficiency of broken kernels of the XT3.

The XT3 had the highest reproducibility among the three models when working with rye. The replicates effect was not significant for any of the models.

Separation by the Mechanical Shaker

The results of sound/broken fractions separated by the mechanical shaker using the designated sieve (1.64mm x 9.52mm) are presented in Table A-88.

Table 16 presents the projected increase at different moisture content and impurity levels for the XT3.

TABLE 16. Projected Increase of Overall Removal Efficiency at Different Moisture Contents and Impurity Levels for the CD-XT3 with Rye

	Impurity level		
Moisture content	5%	10%	15%
11%	71.4%	70.9%	73.0%
15%	71.2%	72.9%	74.2%

Since about 7.52 percent of the sound kernel fraction is broken kernels, using sieve #4 on the XT3 could improve the removal efficiency of broken kernels and the overall removal efficiency from 7.28 to 91.15 percent and 16.92 to 90.5 percent, respectively.

Analysis of the Official Grading by the KSGIS

Results of the KSGIS analysis and the results from this experiment are compared in Figures 22 and 23. The relationship between the two analyses reflect similar characteristics as for hard red spring wheat. The line of the Labofix has a slope close to 1, indicating that the Labofix removed about the same quantity of impurities that is reported by the KSGIS. The N.S.L. and XT3 removed much fewer impurities than was reported by the KSGIS.

Analysis of Applicability

Taking into account such factors as removal efficiency, precision, reproducibility, ease of operation, and operational problems, the Labofix model was the most appropriate model with rye.

Although the XT3 indicated the highest reproducibility, the high precision and efficiency results of the Labofix made it more applicable that the XT3.

Flaxseed

Means and Standard Deviations

The results of means and standard deviations for different fractions using the three models of cleaning machines at impurity levels of 5, 10, and 15 percent are presented in Tables A-25 through A-30 in the Appendix.

Removal Efficiencies

Tables A-55A through A-60A summarize the calculated values of overall removal efficiencies of three replicates at impurity levels of 5, 10, and 15 percent for the three models of cleaning machines tested. The values in this tables are also presented graphically in Figures 24 and 25.

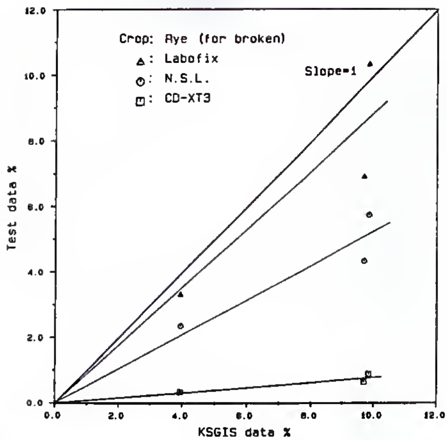


Figure 22. Comparison Between Results from KSGIS and Test Data on Broken Materials Removed

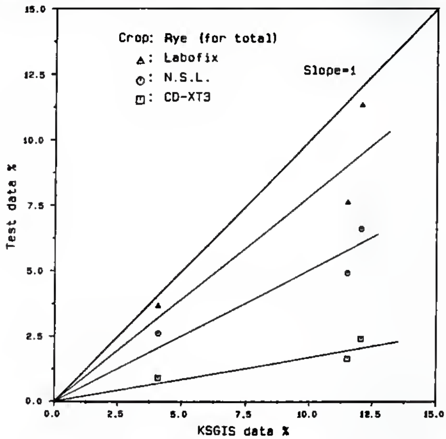


Figure 23. Comparison Between Results from KSGIS and Test Data on Total Impurities Removed

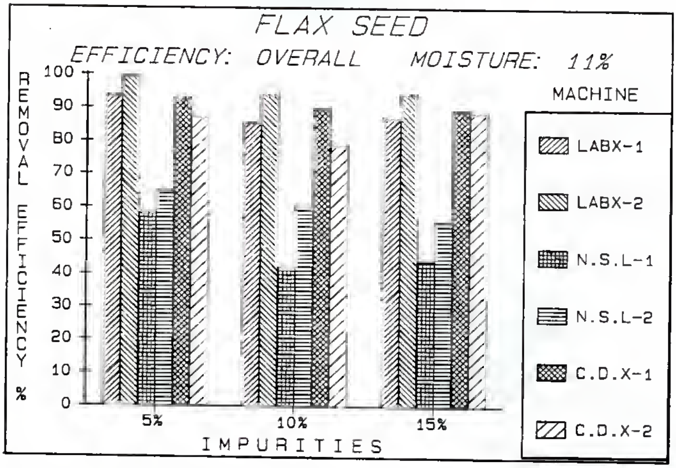


Figure 24. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L., and XT3 Models for Flaxseed at 11% Moisture

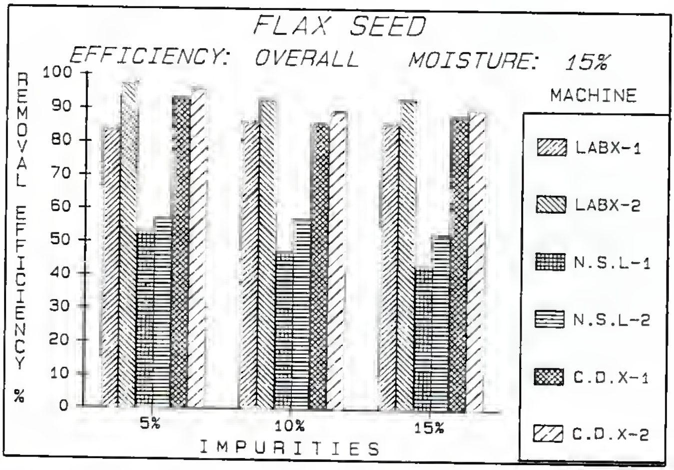


Figure 25. Overall Removal Efficiency by Two Units Each of Labofix, N.S.L., and XT3 Models for Flaxseed at 15% Moisture

Average overall removal efficiencies of the three machines were found to be in the following order:

Labofix > XT3 > N.S.L.

The ranges of average overall removal efficiency for the three machines tested were: from 85 to 99 percent for the Labofix; from 79 to 95 percent for the XT3; and from 52 to 64 percent for the N.S.L.

Removal efficiencies of light materials, foreign materials, and broken kernels are presented in Tables A-55B through A-60B. These values are also shown in Figures A-25 through A-30. The removal efficiency of each component of impurities was as follows:

η_l for light materials: Labofix > XT3 > N.S.L.

η_f for foreign materials: XT3 > Labofix > N.S.L.

η_b for broken kernels: XT3 > Labofix N.S.L.

Effect of Moisture Content

For the overall removal efficiency, the statistical analysis showed that the effect of moisture content was not significant for the models and units except, unit 1 of the Labofix and unit 2 of the XT3 (Table A-61). There was no linear relationship between moisture content and overall removal efficiency (Table A-93).

There was no effect of the moisture content on the removal efficiency of light materials except for unit 2 of the XT3. It must be noted that the removal efficiency of light materials of the Labofix was modified.

Moisture content had no significant effect on the removal efficiency of foreign material for the units and models except unit 2 of the N.S.L. and unit 2 of the XT3.

The effect of the moisture content on the removal efficiency of broken kernels was not significant for the units and models except unit 2 of the Labofix.

Effect of the Impurity Level

The effect of the impurity level on the overall removal efficiency was significant for all units and models except for unit 1 of the Labofix and unit 2 of the N.S.L., but there was no linear association.

The effect of the impurity level on the removal efficiency of light materials was significant for unit 1 of the N.S.L. and for botb units of the XT3. It was not significant for unit 2 of the N.S.L. and for both units of the Labofix.

For the removal efficiency of foreign materials the effect of the impurity level was not significant for all units and models except for unit 2 of the XT3.

The effect of the impurity level on the removal efficiency of broken kernels was significant for all units and models except for units 1 of the Labofix and N.S.L., but there was no linear association.

Analysis of Precision

Table 17 presents the results for average coefficient of variance.

TABLE 17. Average Coefficient of Variance for Overall Removal Efficiency with Flaxseed

Unit	Labofix	N.S.L.	CD-XT3
1	3.93%	16.53%	3.12%
2	3.61%	9.40%	6.33%
Average	3.77	12.97	4.73

Tables A-82 through A-85 present the coefficient of variance for different removal efficiencies. The coefficient of variance for overall removal efficiency was 3.77 percent for the Labofix; 4.73 percent for the XT3; and 19.97 percent for the N.S.L. Based on the coefficient of variance, the ranking for precision was as follows:

Labofix > XT3 > N.S.L.

Labofix has the highest precision, followed by the XT3. The coefficient of variance for the N.S.L. was 19.97 percent, which is much larger than 10 percent, indicating that the precision of the N.S.L. is not acceptable.

The Labofix model reflected poor precision for the removal efficiency of foreign materials, but high precision for the removal efficiency of broken materials. Neither the N.S.L. nor the XT3 met the precision requirements for the removal efficiency of light materials, foreign materials and broken kernels.

Analysis of Reproducibility

The units effect was significant on the overall removal efficiency of the Labofix and the N.S.L., but was not significant for the XT3. For the removal efficiency of light materials the units effect was significant for the N.S.L. and XT3.

The units effect on the removal efficiency of foreign materials was significant for the Labofix.

The units effect on the removal efficiency of broken kernels was significant for the Labofix and N.S.L.

The XT3 had the highest reproducibility.

Analysis of Applicability

Although the XT3 had the highest reproducibility, the Labofix had the highest efficiency, and precision and, therefore, was more applicable for flaxseed. Both models had serious problems with clogged sieves. Because the XT3 did not have a system to keep the sieves clean, this caused a reduction in the capacity of the sieves and increased testing time.

Summary of Overall Efficiencies

Table 18 presents the average values of overall efficiencies for total impurities for the five crops tested, and Tables 19 and 20 present the means and standard deviations and ranges of overall removal efficiency corresponding to each unit and at different moisture contents for each unit.

TABLE 18. Average Values of Overall Efficiencies for Total Impurities

	Labofix	N.S.L.	XT3
HRS Wheat	90.4%	41.9%	15.9%
White Wheat	83.4%	40.1%	16.9%
Grain Sorghum	79.7%	58.3%	65.3%
Rye	74.9%	48.5%	16.9%
Flaxseed	91.2%	53.0%	89.2%

Strengths and Weaknesses

Since each machine used different mechanisms to clean and to separate the sample, results produced by each machine also differed; the Labofix removed most of the broken kernels by using an indented cylinder, the N.S.L. removed most of the light materials by using a powerful air system, and the XT3 removed most of the foreign materials by using a riddle.

Each machine also encountered different problems. The presieve of the Labofix became clogged because the oscillatory movement was not strong enough to keep a continuos grain flow. Pieces of fabric covering the N.S.L. sieves to retain the grain longer also retained foreign materials that could not pass on through. After each test, the operator opened the doors to remove the remaining materials. Whenever foreign materials were retained, it was necessary to remove the materials and weigh them. This was inconvenient, since it extended the testing time. Also, the hopper door of the N.S.L. #2 sometimes did not open and had to be opened manually.

The N.S.L. feeder caused problems during the experiment. First, it was difficult to set the grain flow in order to give a testing time of three minutes. Setting the feed control at number 2 resulted in a testing time longer than three minutes, but setting the feed control at number 4 shortened testing time to less than one minute. Since the N.S.L. feeder does not have a continuous

TABLE 19. Means ± Standard Deviation and Range for Overall Removal Efficiency Corresponding to Each Unit and Crop Tested

Crop	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	89.04 ± 5.63 80.1 ~ 103.6	91.67 ± 3.11 88.4 ~ 99.0	32.56 ± 3.81 24.6 ~ 37.20	51.32 ± 5.86 37.7 ~ 58.8	16.13 ± 1.77 13.0 ~ 19.2	15.63 ± 1.20 13.9 ~ 17.4
White Wheat	81.52 ± 10.92 65.5 ~ 99.9	85.37 ± 6.99 70.2 ~ 94.4	42.32 ± 11.73 29.2 ~ 73.3	37.87 ± 8.47 24.2 ~ 54.2	17.61 ± 3.42 12.9 ~ 27.3	16.27 ± 3.3 66 ~ 19.5
Grain Sorghum	79.55 ± 4.49 73.8 ~ 88.6	79.83 ± 3.54 72.9 ~ 87.2	58.54 ± 2.84 54.3 ~ 64.4	58.13 ± 3.14 53.6 ~ 64.7	63.62 ± 3.86 54.3 ~ 68.6	66.91 ± 4.85 60.2 ~ 72.5
Rye	72.96 ± 4.32 65.4 ~ 83.5	76.89 ± 2.07 72.4 ~ 80.5	41.86 ± 4.69 33.5 ~ 50.4	55.2 ± 11.99 23.3 ~ 81.6	16.45 ± 1.61 14.2 ~ 18.5	17.41 ± 2.67 14.6 ~ 24.4
Flaxseed	87.08 ± 3.42 82.4 ~ 95.6	95.23 ± 3.44 88.9 ~ 100.0	48.08 ± 7.95 35.2 ~ 64.6	57.89 ± 5.44 52.1 ~ 71.4	89.83 ± 2.8 85.3 ~ 95.2	88.49 ± 5.6 75.9 ~ 96.4

scale, it was impossible to set the feed control to a specific testing time. Another problem with the N.S.L. feed control at a setting of 2 was that some foreign materials could not pass through because the opening was so small. Since the N.S.L. feeder retained part of the sample, it also clogged.

The container for light materials of the N.S.L. did not have sufficient storage capacity. When the impurity level was 15 percent, the container for light materials was full and part of the light materials fraction was blown away.

The riddle used by the XT3 sometimes removed large sound kernels of the grain tested. This

TABLE 20. Means ± Standard Deviations and Ranges of Overall Removal Efficiency at Different Moisture Contents for Each Model (MC1 = 11% and MC2 = 15% Moisture Content

Crop	Labofix		N.S.L.		CD-XT 3	
	MC 1	MC 2	MC 1	MC 2	MC 1	MC 2
HRS Wheat	90.49 ± 2.53 87.0 ~ 93.0	90.22 ± 6.21 80.1 ~ 103.6	41.47 ± 11.50 24.6 ~ 58.8	42.41 ± 10.11 29.4 ~ 57.8	16.84 ± 1.27 14.8 ~ 19.2	14.92 ± 1.05 13.0 ~ 18.0
White Wheat	78.14 ± 9.08 65.5 ~ 90.7	88.75 ± 4.82 79.3 ~ 99.9	35.42 ± 5.0 24.2 ~ 45.4	44.77 ± 12.19 31.7 ~ 73.3	16.13 ± 4.18 6.6 ~ 27.3	17.76 ± 2.18 12.9 ~ 21.1
Grain Sorghum	81.75 ± 3.84 76.9 ~ 88.6	77.63 ± 3.0 72.9 ~ 82.0	59.73 ± 2.93 54.3 ~ 64.7	56.94 ± 2.30 53.6 ~ 60.5	64.22 ± 4.95 54.3 ~ 74.2	66.32 ± 4.20 58.2 ~ 72.5
Rye	74.58 ± 3.93 65.4 ~ 79.0	75.27 ± 3.96 68.9 ~ 83.5	46.14 ± 4.80 39.4 ~ 53.6	50.9 ± 15.0 23.3 ~ 81.6	15.46 ± 1.15 14.2 ~ 19.1	18.37 ± 2.1 16.3 ~ 19.1
Flaxseed	92.42 ± 5.22 84.0 ~ 100.2	89.89 ± 5.30 82.9 ~ 101.80	54.25 ± 10.48 35.2 ~ 71.4	51.72 ± 5.52 42.1 ~ 59.6	87.94 ± 4.92 75.9 ~ 93.6	90.39 ± 3.56 85.3 ~ 96.4

was inconvenient since the large sound kernels had to be hand picked in order to determine the foreign materials fraction.

The XT3 does not have a sieve cleaning system. After running two tests, the sieves were clogged and cleaning was necessary. In order to obtain accurate results, the sieve was cleaned after each test and the materials recovered from the sieves were added to the corresponding fraction.

The air system of the XT3 blew away a lot of light materials, which increased the sample loss and produced an erroneous result about the light material content of the sample. Also, when the sample contained powder, a portion was carried by the riddle and deposited in the foreign material fraction.

The testing time for the XT3 was the actual time required for foreign materials to pass completely over the riddle. Because of the characteristics of the riddle movement, some foreign materials, such as soybeans, kept moving back and forward and required more time to pass all the way over the riddle.

Table 21 summarizes the advantages and disadvantages of each model and Table 22 presents an evaluation summary for separation performance of the three cleaning models tested.

TABLE 21. Strengths and Weaknesses Observed for the Three Models Tested

Strengths and Weaknesses Observed for the Three Models Tested			
	Labofix	N.S.L.	CD-XT3
Strength	removes broken kernels with indented cylinder removes light materials with a cyclone collector high removal efficiency	removes light materials with double suction aspiration system compact structure	removes foreign materials with a riddle good reproducibility
Weakness	problems in feeding system and adjustment of trough longer testing time lower reproducibility	problems in feeding system cloth guard retained grain kernels on sieve needs proper size of sieves for brokens lower reproducibility	problem in sieve-self cleaning aspirator blew dust to the room air needs additional sieves for brokens

TABLE 22. Summary Evaluation of the Separation Performance for the Three Models (Ranking)

	Model		
Factor	Labofix	N.S.L.	CD-XT3
Accuracy	3	2	1
Precision	3	1	2
Reproducibility a. Replicate	2	3	2
b. Unit	1	2	3
Applicability	3	2	1
Ease of operation a. Testing time	1	2	3
b. Noise level	3	1	2
c. Others	1	2	3
Tests vs KSGIS	3	2	1

3 = best, 2 = good, 1 = fair.

Ease of Operation

In order to analyze the ease of operation of each model, the following features have been considered: feed control, air control, sieve cleaning, and sieve changing.

The feed control of the XT3 and Labofix did not experience any difficulties. Both maintained a constant and continuous grain flow. Since these two feed controls have a continuous scale, it was easy to adjust the grain flow to the test requirements. Although the N.S.L. has a discrete scale, the most convenient scale for standardized testing, the fixed settings do not fit the desired grain flow.

For some crops, a setting of 2 produced a grain flow that was too slow, but a setting of 4, the next setting point, was too fast.

All three models have convenient air control. Since all air controls were continuous scale, it was simple to adjust the air flow to the point where most of the light materials could be removed.

The N.S.L. had the most efficient mechanism to keep sieves clean, which consisted of a box and rubber balls located under the screens. The box was made up of wires, allowing the balls to touch the screens. Screen movement, which was the same as that of the box, caused the balls to hit the screens, thereby keeping the screens clean.

The Labofix has an effective mechanism to keep the sieve clean utilizing a brush affixed to the wall of the machine. The brush always touched the sieves and, because of the rotary movement of the sieves, kept the sieve clean.

The lack of a sieve cleaning mechanism was one of the disadvantages of the XT3. Failure to clean the sieve manually after each test so that recovered materials could be added to the corresponding fractions would produce inaccurate test results. The clean-up operation required time and introduced a risk of sample loss.

Whenever samples of different crops were analyzed, the sieve changing operation became an important factor. Changing the XT3 sieve required the least amount of time and was the easiest to perform. Changing the N.S.L. sieve was a little more difficult than changing the sieve of the XT3, and changing the sieves of the Labofix was the most difficult.

All the factors concerning the ease of operation are analyzed in Table 23. A number from 1 to 3 was assigned to each model for each crop and for each factor. The number 3 represented excellent, 2 represented good and 1 represented fair. The last column in Table 23 shows the average of the four numbers assigned to each model according to the ease of operation. From these averages, it can be observed that the ease of operation of the XT3 is equal or better than the N.S.L. and Labofix in all cases.

TABLE 23. Ranking Numbers for Feed and Air Control, Sieve Cleaning and Changing Parts

Crop	Model	F	A	S	C	AV
HRS Wheat	Labofix	3	3	3	1	2.50
	N.S.L.	1	3	1	2	1.75
	CD-XT 3	3	3	1	3	2.50
White Wheat	Labofix	3	3	1	1	2.00
	N.S.L.	1	3	3	2	2.25
	CD-XT 3	3	3	1	3	2.50
Grain Sorghum	Labofix	3	3	3	1	2.50
	N.S.L.	1	3	3	2	2.25
	CD-XT 3	3	3	2	3	2.75
Rye	Labofix	3	3	3	1	2.50
	N.S.L.	1	3	3	2	2.25
	CD-XT 3	3	3	2	3	2.75
Flaxseed	Labofix	3	3	2	1	2.25
	N.S.L.	1	3	3	2	2.25
	CD-XT 3	3	3	2	3	2.75

F: Feed control
A: Air control
S: Sieve cleaning
C: Changing parts

Testing Time

Table 24 shows the means of testing time for each unit and each crop. The means of testing times were as follows:

Labofix > N.S.L. > XT3

The grain flow rate in the Labofix and N.S.L. was adjusted in order to obtain a testing time not longer than three minutes. With the feed control set up according to the standards of the U.S. Department of Agriculture, the testing time of 2.03 min. for the XT3 was the shortest. A testing time

TABLE 24. Average Testing Times (minutes) of the Three Models for the Five Crops Tested

Model / Crop	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	2.56	2.50	2.19	5.24	1.75	1.72
White Wheat	3.11	3.43	2.02	1.82	1.33	1.33
Grain Sorghum	2.70	2.73	2.43	3.49	2.28	2.03
Rye	2.42	3.01	3.09	3.46	2.59	2.11
Flaxseed	2.84	4.23	1.13	4.77	2.62	2.56
Average	2.73	3.18	2.17	3.75	2.11	1.95
	2.95		2.96		2.03	

of 2.96 min. for the N.S.L. was obtained by setting the feed control at number 2, the smallest setting point of the scale. Use of the next setting point would shorten the the testing time too much.

The closest testing time to three minites was obtained by using the Labofix. Because the Labofix utilized a continuous scale for the feed control, it was possible to set the feed control at the point where the testing time was close to three minutes.

There were three testing times that differed from the maximum testing time set up for this experiment. These testing times were 5.24 min. for the HRS wheat when working with unit 2 of the N.S.L., 4.77 min. for flaxseed when working with unit 2 of the N.S.L., and 4.23 min. when working with unit 2 of Labofix.

Testing times longer than three minutes for the N.S.L. were caused by clogging of the feeder when the grain contained large foreign materials. When the feeder clogged, the grain flow rate decreased and the the testing time increased.

Testing times longer than three minutes for the Labofix when working with flaxseed were the result of clogging of the presieve by foreign materials. One reason could have been the capacity of the presieve. When the impurity content was 15 percent, the presieve clogged with foreign materials in a large enough quantity to affect the grain flow rate. The grain had less space to pass through and the sample required longer to pass through the entire machine. Another reason could have been that the movement of the sieve was not strong enough to make the grain pass through the presieve. The vibratory system was not easy to adjust and it was difficult to set the vibrations of the sieve of both Labofix units to the same intensity.

Noise Level

The noise level was measured by using a noise meter. Measurements were taken one foot from the machine, in the same location the operator must stand when operating the cleaner.

The noise level produced by each model was found to be as follows:

N.S.L. > XT3 > Labofix

The average noise level was 89.18 dB for the N.S.L., 88.73 dB for the XT3, and 80.42 dB for the Labofix. The noise level produced by the three machines were significantly different, but the noise produced by the Labofix was much lower than that produced by the N.S.L. and the XT3.

The noise level depended on the crop being analyzed. The larger the kernel, the higher the noise level produced by the cleaners. As an example, the mean for soft white wheat was 86.03 dB, while for rye and flaxseed the means were 83.5 and 82.9 dB, respectively.

Table 25 shows the average of three measurements corresponding to each model and to each crop. The last row presents the average for each model.

TABLE 25. Average Noise Level Measurement (decibels) of the Three Models for the Five Crops Tested

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRS Wheat	78.50	89.67	86.50
White Wheat	81.00	88.93	88.17
Grain Sorghum	80.67	89.50	90.00
Rye	77.43	89.07	84.00
Flaxseed	75.50	88.83	84.50
Average	80.42	89.18	88.73

CONCLUSIONS

All three models tested in this experiment have different designs and use different mechanisms to remove and classify impurities, and each model has outstanding features.

The Labofix model had the highest overall removal efficiency and removal efficiency of broken kernels. It utilized an indented cylinder, which has been proven the most adequate mechanism for removal of a cross-section of broken kernels, and a pneumatic separation system which removed most of the light materials. The fine sieve removed a major portion of the broken and shrunken kernels. There were difficulties, however, with the feeding systems for crops such as flaxseed, wheat, rye, and sorghum when the impurity level was high.

The N.S.L. model produced the highest removal efficiency of light materials. Its powerful pneumatic separation system removed almost all of the light materials. However, the N.S.L. feeding system did not allow sound foreign materials to pass through and did become clogged. There was no continuous scale for feed control, which made it difficult to adjust grain flow to a specific rate.

The XT3 model had the highest removal efficiency of foreign materials by using a riddle which removed most foreign material. Another outstanding feature of the XT3 was its high reproducibility. However, because it does not have a sieve cleaning system, the sieves do clog and need cleaning after each test. The pneumatic separation system blows away part of the light material fraction so that it cannot be weighed.

Overall removal efficiency was affected equally by moisture content and impurity level.

For all crops, the Labofix separated an amount equal to or more impurities than the amount reported by the KSGIS, except for rye. The XT3 and the N.S.L. removed smaller amounts of impurities than the amounts reported by the KSGIS, except for sorghum.

Combining the outstanding features of each model could result in a new, improved grain cleaner.

Recommendations

Removal efficiencies and separation of impurity fractions could be improved by testing different settings for the air control, feed control, and tray angle. The settings for the N.S.L. and Labofix models were selected by testing the cleaner with sound whole kernel samples. The airflow control of the N.S.L. and Labofix were set by passing a 1-kg sample of sound whole kernels through and increasing the airflow to the maximum setpoint where the airflow began to pick up sound kernels in the light material pans.

Feed control for the Labofix unit was set by passing a 1-kg sample of sound kernels through the cleaner and adjusting the flow rate control until reaching a test time of under three minutes. The tray angle of the Labofix was set by passing through a 1-kg sample of sound kernels and increasing the angle to the point just before the cleaner began removing sound kernels from the broken kernel pan.

Some of the difficulties experienced in this experiment were caused by the manner of selecting the machine settings. A sound kernel sample and a grain mixture sample react differently. Since grain samples with impurities take longer to pass through the machines, some testing times were longer than three minutes. The pneumatic separators of the N.S.L. and Labofix models removed broken kernels as light materials because the airflow was too high.

It is important in grain grading to remove and separate the impurities in well defined fractions as light material, foreign material, and broken kernels. After testing different air control settings with samples of known, specific amounts of light materials and broken materials, the appropriate control setting was determined by weighing the impurity fractions and choosing the setting where the maximum amount of light material was removed without removing broken kernels. Setting the fed control must be selected by using samples with impurities. By analyzing the results of efficiency at different settings, a better control setting could be determined and it might be possible to increase the removal efficiency of the grain cleaner.

Difficulties with the N.S.L. feeder could be solved by using a rolling bar as a feeder rather than a vibrating sheet. This would eliminate the need for the automatic door opener. The weight of the cloth guard must be lighter in order to avoid trapping foreign materials. It would also be convenient to use a continuous scale for the feed control. The difficulties encountered with some crops in setting the flow rate control were caused by an inadequate number of set points on the discrete scale. The N.S.L. container for light materials should be larger in order to contain of the light material when the impurity level is high.

The capacity of the Labofix presieve could be increased by increasing the vibration intensity or by using a larger sieving area. Using a rolling bar as a feeder for the Labofix is convenient and gives more precise flow rate control.

A self-cleaning sieve system is needed for the XT3 model. A box of balls under the sieve has proven an effective method for keeping sieves clean. The XT3 also needs a cyclone in order to have complete separation of the light material fraction.

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ACKNOWLEDGEMENTS

I would like to give special thanks to Dr. Do Sup Chung and Dr. Charles Spillman, my major professors, for their advice, guidance, and encouragement throughout my studies at Kansas State University. I also appreciate Dr. Raja Nassar and Dr. Elieser Posner, members of my graduate committee, who provided guidance and advice throughout this research.

I would like to express my gratitude to all the personnel of the Department of Agricultural Engineering for the help and kindness they have shown me during these years. Special thanks go to Sheri Shanks for her invaluable help in typing this thesis and to my friend and classmate, Yu-Jie Wang, who made the time spent working together on this research very special indeed.

APPENDIX

TABLE A-1. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Hard Red Spring Wheat

Machine: CD-XT 3-1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.93 ± 0.12	3.50 ± 0.40	5.23 ± 0.12
	15	2.17 ± 0.21	3.53 ± 0.25	5.90 ± 0.26
S2B	11	3.40 ± 0.35	7.23 ± 0.25	11.27 ± 0.46
	15	3.53 ± 1.24	7.87 ± 0.21	11.60 ± 0.17
S3B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S4B	11	989.03 ± 0.42	981.57 ± 0.76	975.23 ± 0.15
	15	991.50 ± 1.32	984.03 ± 0.25	974.43 ± 0.57
S5B	11	0.30 ± 0.00	0.57 ± 0.06	0.67 ± 0.15
	15	0.37 ± 0.15	0.60 ± 0.17	1.07 ± 0.12
S6B	11	4.53 ± 0.51	6.43 ± 0.59	5.67 ± 0.25
	15	1.80 ± 0.26	2.60 ± 0.35	4.23 ± 0.12

TABLE A-2. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Hard Red Spring Wheat Machine: CD-XT 3-2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.97 ± 0.06	2.73 ± 0.32	5.10 ± 0.10
	15	1.73 ± 0.06	3.67 ± 0.29	5.10 ± 0.17
S2B	11	3.40 ± 0.20	7.47 ± 0.12	11.23 ± 0.25
	15	4.20 ± 0.17	7.90 ± 0.17	11.77 ± 0.21
S3B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S4B	11	989.90 ± 0.26	981.47 ± 1.37	974.03 ± 0.05
	15	990.17 ± 0.15	984.10 ± 0.78	975.57 ± 0.47
S5B	11	0.20 ± 0.00	0.50 ± 0.00	0.70 ± 0.10
	15	0.17 ± 0.06	0.40 ± 0.10	0.50 ± 0.10
S6B	11	4.00 ± 0.26	6.37 ± 0.67	6.33 ± 0.29
	15	1.43 ± 0.06	2.80 ± 0.10	3.93 ± 0.23

TABLE A-3. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Hard Red Spring Wheat

Machine: Labofix-1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	7.73 ± 0.60	18.87 ± 3.06	27.67 ± 3.20
	15	10.70 ± 2.70	14.20 ± 0.46	21.87 ± 0.49
S2B	11	2.87 ± 0.24	5.50 ± 0.78	7.53 ± 0.67
	15	2.80 ± 0.17	5.80 ± 0.87	7.43 ± 0.91
S3B	11	14.20 ± 0.30	28.80 ± 1.30	42.80 ± 0.62
	15	13.73 ± 0.70	28.17 ± 1.19	41.87 ± 0.24
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	957.23 ± 0.25	911.77 ± 1.90	865.70 ± 1.97
	15	953.40 ± 0.71	917.20 ± 2.29	871.63 ± 0.87
S6B	11	18.70 ± 1.17	37.40 ± 2.09	60.37 ± 2.04
	15	21.20 ± 0.20	33.80 ± 2.61	57.30 ± 0.90

TABLE A-4. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Hard Red Spring Wheat   Machine: Labofix-2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	9.00 ± 0.10	14.40 ± 1.14	22.30 ± 1.30
	15	7.77 ± 0.32	15.87 ± 2.42	23.10 ± 1.56
S2B	11	2.53 ± 0.23	5.60 ± 0.80	6.90 ± 1.15
	15	2.93 ± 0.47	4.50 ± 0.53	6.93 ± 1.01
S3B	11	14.63 ± 0.06	29.33 ± 1.65	41.27 ± 2.00
	15	14.87 ± 0.23	26.47 ± 2.36	37.20 ± 1.76
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	954.87 ± 1.25	907.37 ± 1.06	864.23 ± 1.77
	15	950.03 ± 0.94	907.37 ± 3.59	863.13 ± 1.41
S6B	11	19.07 ± 1.05	42.37 ± 2.32	66.03 ± 1.01
	15	23.00 ± 0.70	43.30 ± 1.47	67.17 ± 0.68

TABLE A-5. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Hard Red Spring Wheat   Machine: N.S.L.-1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	6.17 ± 1.86	13.63 ± 2.37	17.07 ± 3.14
	15	5.07 ± 0.42	12.87 ± 2.49	16.73 ± 2.78
S2B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S3B	11	0.43 ± 0.44	3.80 ± 1.22	6.23 ± 3.76
	15	2.43 ± 0.12	4.63 ± 0.35	6.87 ± 1.72
S4B	11	983.10 ± 1.37	962.37 ± 3.35	950.83 ± 3.34
	15	980.17 ± 0.59	963.23 ± 2.29	947.93 ± 3.08
S5B	11	4.17 ± 0.25	7.73 ± 1.42	12.33 ± 1.92
	15	4.63 ± 0.35	8.43 ± 0.61	13.50 ± 0.87
S6B	11	2.80 ± 0.17	9.83 ± 1.21	13.80 ± 1.59
	15	4.37 ± 0.15	9.53 ± 0.47	10.60 ± 1.57

TABLE A-6. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Hard Red Spring Wheat Machine: N.S.L.-2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	24.37 ± 1.89	35.17 ± 3.50	44.50 ± 22.13
	15	21.23 ± 0.84	36.00 ± 10.85	43.03 ± 5.16
S2B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S3B	11	0.27 ± 0.38	3.93 ± 0.15	7.47 ± 1.16
	15	2.87 ± 1.05	4.90 ± 0.17	7.33 ± 0.70
S4B	11	967.40 ± 0.86	948.43 ± 1.97	926.13 ± 15.18
	15	970.03 ± 1.46	945.90 ± 4.82	928.87 ± 2.89
S5B	11	0.77 ± 0.12	4.33 ± 1.70	13.17 ± 10.51
	15	1.00 ± 0.10	5.73 ± 7.25	10.67 ± 3.42
S6B	11	2.63 ± 0.12	5.57 ± 0.65	7.83 ± 2.11
	15	3.33 ± 0.06	5.17 ± 0.51	7.23 ± 0.75

TABLE A-7. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: White Wheat   Machine: CD-XT 3 - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	1.61 ± 0.29	2.78 ± 0.49	3.65 ± 0.59
	15	1.33 ± 0.24	1.49 ± 1.25	3.22 ± 0.42
S2B	11	4.64 ± 0.50	8.07 ± 0.13	11.32 ± 0.56
	15	4.10 ± 0.14	8.05 ± 0.38	11.59 ± 0.41
S3B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S4B	11	988.63 ± 2.40	980.47 ± 6.07	971.47 ± 2.57
	15	990.63 ± 2.69	981.33 ± 16.00	970.97 ± 3.02
S5B	11	1.18 ± 0.70	0.54 ± 0.51	0.37 ± 0.30
	15	0.34 ± 0.13	0.22 ± 0.24	0.75 ± 0.11
S6B	11	4.23 ± 2.91	3.74 ± 0.30	10.75 ± 2.03
	15	2.97 ± 0.57	4.92 ± 3.28	15.04 ± 1.71

TABLE A-8. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: White Wheat

Machine: CD-XT 3 - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.41 ± 0.26	2.21 ± 0.49	3.32 ± 0.85
	15	1.29 ± 0.24	3.12 ± 0.42	5.40 ± 0.46
S2B	11	3.73 ± 2.54	7.49 ± 0.50	11.99 ± 0.36
	15	3.89 ± 0.17	6.82 ± 0.42	11.40 ± 0.30
S3B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S4B	11	987.30 ± 6.47	983.87 ± 1.50	976.63 ± 1.58
	15	989.43 ± 1.00	975.07 ± 3.95	972.60 ± 1.97
S5B	11	0.45 ± 0.09	0.39 ± 0.16	1.28 ± 0.26
	15	0.15 ± 0.02	0.62 ± 0.15	0.66 ± 0.18
S6B	11	2.45 ± 0.71	3.47 ± 2.51	7.35 ± 0.95
	15	3.79 ± 0.48	8.00 ± 0.31	8.33 ± 2.05

TABLE A-9. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: White Wheat Machine: Labofix - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	8.14 ± 0.68	13.93 ± 1.59	22.54 ± 3.51
	15	7.00 ± 0.72	13.68 ± 2.37	27.11 ± 6.84
S2B	11	1.36 ± 0.52	3.64 ± 0.42	8.83 ± 1.76
	15	3.27 ± 2.20	2.42 ± 0.40	4.10 ± 1.98
S3B	11	9.56 ± 0.55	20.47 ± 2.39	55.31 ± 3.18
	15	17.80 ± 3.24	27.92 ± 1.60	47.12 ± 1.18
S4B	11	0.00	0.00	0.25 ± 0.22
	15	0.00	0.00	0.00
S5B	11	967.03 ± 0.94	955.86 ± 22.23	865.07 ± 3.67
	15	949.77 ± 5.01	916.87 ± 2.40	873.57 ± 1.22
S6B	11	13.85 ± 0.08	33.72 ± 1.38	47.71 ± 3.69
	15	17.22 ± 1.25	37.78 ± 1.03	55.60 ± 3.01

TABLE A-10. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: White Wheat Machine: Labofix - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	8.49 ± 0.55	13.88 ± 1.33	18.77 ± 0.81
	15	7.62 ± 0.32	18.53 ± 1.97	25.44 ± 2.00
S2B	11	2.11 ± 0.14	2.41 ± 0.58	3.88 ± 0.51
	15	1.25 ± 0.23	2.15 ± 0.31	3.60 ± 0.32
S3B	11	10.51 ± 0.44	28.46 ± 2.06	46.95 ± 3.03
	15	13.58 ± 0.55	29.44 ± 2.44	56.99 ± 1.71
S4B	11	0.04 ± 0.08	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	963.73 ± 2.03	916.17 ± 1.84	869.87 ± 3.08
	15	953.63 ± 0.61	921.14 ± 19.66	893.93 ± 56.09
S6B	11	14.87 ± 0.40	38.62 ± 2.41	59.48 ± 0.90
	15	21.94 ± 0.91	39.93 ± 0.28	51.91 ± 1.02

TABLE A-11. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: White Wheat

Machine: N.S.L. - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	4.47 ± 0.79	23.80 ± 1.66	16.21 ± 3.27
	15	6.26 ± 1.77	12.11 ± 3.02	18.86 ± 2.03
S2B	11	0.00	0.04 ± 0.05	0.02 ± 0.03
	15	0.00	0.00	0.00
S3B	11	7.02 ± 0.72	1.23 ± 0.25	3.35 ± 1.20
	15	19.41 ± 2.28	13.30 ± 1.45	11.53 ± 2.28
S4B	11	976.47 ± 3.71	949.30 ± 16.39	948.77 ± 5.67
	15	963.97 ± 3.34	964.07 ± 10.30	959.47 ± 26.50
S5B	11	2.69 ± 0.68	2.90 ± 0.72	16.96 ± 8.53
	15	2.77 ± 0.25	7.53 ± 2.04	9.95 ± 2.09
S6B	11	5.15 ± 0.79	10.41 ± 1.41	12.83 ± 3.04
	15	4.69 ± 0.60	7.84 ± 1.78	15.02 ± 2.72

TABLE A-12. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: White Wheat

Machine: N.S.L. - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	10.56 ± 2.63	18.53 ± 18.71	14.14 ± 9.07
	15	7.07 ± 2.85	16.73 ± 6.06	16.62 ± 3.21
S2B	11	0.00	0.02 ± 0.03	0.00
	15	0.00	0.00	0.00
S3B	11	2.12 ± 0.30	2.39 ± 2.14	5.96 ± 0.64
	15	8.88 ± 4.22	8.80 ± 2.21	6.95 ± 2.16
S4B	11	955.67 ± 29.18	957.60 ± 20.91	950.30 ± 3.84
	15	971.63 ± 0.71	996.40 ± 3.89	946.60 ± 2.42
S5B	11	2.45 ± 1.30	9.82 ± 8.73	20.56 ± 6.10
	15	6.08 ± 1.76	12.92 ± 8.26	16.02 ± 4.31
S6B	11	3.35 ± 0.36	3.95 ± 0.99	5.81 ± 0.94
	15	2.58 ± 0.17	4.85 ± 0.38	8.56 ± 0.30

TABLE A-13. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Grain Sorghum Machine: CD-XT 3 - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S2B	11	1.30 ± 0.53	1.97 ± 0.06	2.90 ± 0.61
	15	0.90 ± 0.40	1.90 ± 0.17	2.77 ± 0.29
S3B	11	957.20 ± 1.17	941.00 ± 3.26	906.03 ± 0.35
	15	963.13 ± 0.50	935.27 ± 0.50	900.43 ± 1.17
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	21.43 ± 1.19	33.63 ± 2.95	56.20 ± 0.70
	15	20.80 ± 0.75	38.20 ± 1.01	60.17 ± 1.19
S6B	11	11.27 ± 0.93	22.27 ± 0.15	33.57 ± 0.11
	15	11.80 ± 0.35	22.27 ± 0.68	34.20 ± 0.17

TABLE A-14. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Grain Sorghum

Machine: CD-XT 3 - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S2B	11	1.07 ± 0.06	1.80 ± 0.17	2.63 ± 0.15
	15	1.00 ± 0.30	1.70 ± 0.10	2.67 ± 0.32
S3B	11	955.67 ± 1.54	933.00 ± 4.03	904.07 ± 0.50
	15	965.40 ± 3.55	926.33 ± 3.55	890.27 ± 1.22
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	22.70 ± 1.71	41.07 ± 4.73	57.70 ± 0.87
	15	19.03 ± 2.94	45.93 ± 0.72	71.73 ± 1.06
S6B	11	11.60 ± 0.10	21.73 ± 0.49	33.20 ± 0.35
	15	11.20 ± 0.40	22.10 ± 0.44	32.87 ± 0.25

TABLE A-15. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Grain Sorghum

Machine: Labofix - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	18.80 ± 0.26	36.77 ± 1.47	56.20 ± 2.80
	15	18.40 ± 2.60	33.87 ± 0.68	50.33 ± 1.14
S2B	11	0.73 ± 0.15	1.80 ± 0.10	3.17 ± 0.51
	15	1.10 ± 0.00	2.30 ± 0.10	3.17 ± 0.15
S3B	11	23.23 ± 0.81	37.17 ± 1.01	53.93 ± 1.80
	15	17.30 ± 0.61	34.27 ± 3.15	54.10 ± 1.35
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	955.53 ± 0.50	921.50 ± 0.71	877.13 ± 3.08
	15	962.47 ± 0.35	923.23 ± 3.50	882.43 ± 1.58
S6B	11	1.00 ± 0.20	2.37 ± 0.06	9.07 ± 0.91
	15	1.67 ± 0.12	5.70 ± 0.20	7.97 ± 0.38

TABLE A-16. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Grain Sorghum Machine: Labofix - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	18.60 ± 0.72	40.10 ± 0.66	54.83 ± 1.15
	15	19.17 ± 0.15	35.63 ± 0.90	54.00 ± 1.31
S2B	11	0.83 ± 0.15	1.77 ± 0.21	2.93 ± 0.06
	15	1.50 ± 0.44	2.17 ± 0.06	3.07 ± 0.12
S3B	11	21.27 ± 0.81	33.73 ± 0.87	56.83 ± 3.79
	15	18.20 ± 0.10	35.53 ± 2.50	56.50 ± 4.67
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	956.63 ± 0.79	921.87 ± 0.94	878.97 ± 4.54
	15	959.60 ± 0.71	922.57 ± 3.39	880.13 ± 5.17
S6B	11	1.63 ± 0.32	3.23 ± 0.06	5.20 ± 0.26
	15	1.90 ± 0.10	2.73 ± 0.55	3.53 ± 0.15

TABLE A-17. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Grain Sorghum　　　　Machine: N.S.L. - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	5.63 ± 0.99	4.73 ± 1.72	9.53 ± 6.99
	15	1.33 ± 0.29	7.93 ± 1.40	13.10 ± 3.57
S2B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S3B	11	0.27 ± 0.06	0.07 ± 0.12	0.23 ± 0.06
	15	0.80 ± 0.35	0.47 ± 0.38	2.00 ± 2.51
S4B	11	965.53 ± 1.50	936.60 ± 0.79	910.90 ± 5.44
	15	967.90 ± 0.71	938.33 ± 2.62	906.77 ± 0.61
S5B	11	11.03 ± 0.42	31.27 ± 0.81	35.53 ± 4.74
	15	11.70 ± 0.72	22.40 ± 0.44	33.20 ± 1.25
S6B	11	14.50 ± 0.66	22.73 ± 1.93	40.90 ± 3.89
	15	13.67 ± 0.21	27.50 ± 1.00	39.90 ± 1.15

TABLE A-18. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Grain Sorghum   Machine: N.S.L. - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	6.73 ± 0.81	14.70 ± 0.52	23.97 ± 2.78
	15	5.70 ± 0.56	14.63 ± 1.27	14.93 ± 1.80
S2B	11	0.00	0.00	0.00
	15	0.00	0.07 ± 0.12	0.00
S3B	11	0.10 ± 0.17	0.27 ± 0.46	1.20 ± 1.66
	15	0.63 ± 0.84	0.93 ± 1.62	1.13 ± 1.06
S4B	11	965.67 ± 7.43	932.73 ± 4.43	902.30 ± 4.18
	15	968.13 ± 1.32	937.40 ± 2.92	912.03 ± 0.94
S5B	11	9.77 ± 0.06	17.73 ± 0.06	30.13 ± 4.91
	15	9.30 ± 0.46	18.37 ± 0.67	27.43 ± 2.49
S6B	11	13.00 ± 0.80	24.50 ± 0.62	38.93 ± 0.68
	15	12.70 ± 0.26	24.93 ± 0.38	37.40 ± 1.00

TABLE A-19. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Rye

Machine: CD-XT 3-1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.74 ± 0.03	1.57 ± 0.06	3.67 ± 0.12
	15	2.13 ± 0.12	4.20 ± 0.44	4.67 ± 0.45
S2B	11	3.45 ± 0.06	6.37 ± 0.58	10.30 ± 0.10
	15	4.33 ± 0.49	8.00 ± 0.70	10.73 ± 0.25
S3B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S4B	11	991.33 ± 0.15	984.07 ± 0.63	975.50 ± 1.12
	15	988.87 ± 0.50	980.10 ± 0.79	972.07 ± 0.50
S5B	11	0.51 ± 0.10	1.13 ± 0.15	1.10 ± 0.17
	15	0.20 ± 0.00	0.60 ± 0.00	1.20 ± 0.10
S6B	11	2.64 ± 0.03	5.73 ± 0.15	7.90 ± 0.62
	15	2.40 ± 0.61	5.40 ± 0.44	9.47 ± 0.64

TABLE A-20. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Rye

Machine: CD-XT 3-2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.70 ± 0.08	2.13 ± 0.76	3.87 ± 0.32
	15	2.03 ± 0.25	3.77 ± 0.12	5.40 ± 0.10
S2B	11	3.59 ± 0.31	6.60 ± 0.17	10.80 ± 0.30
	15	5.90 ± 0.52	7.90 ± 0.44	11.40 ± 0.20
S3B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S4B	11	991.20 ± 0.71	984.70 ± 1.77	975.47 ± 0.61
	15	988.13 ± 0.71	979.40 ± 0.35	974.00 ± 0.35
S5B	11	1.31 ± 0.23	1.03 ± 0.15	1.17 ± 0.25
	15	0.47 ± 0.15	0.63 ± 0.12	1.00 ± 0.20
S6B	11	3.14 ± 0.46	5.60 ± 0.30	6.83 ± 0.15
	15	2.83 ± 0.25	5.33 ± 0.06	6.80 ± 0.10

TABLE A-21. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Rye

Machine: Labofix-1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	3.40 ± 0.54	8.23 ± 1.01	16.67 ± 1.53
	15	5.20 ± 0.44	9.30 ± 0.56	12.97 ± 1.88
S2B	11	0.86 ± 0.03	2.63 ± 0.86	4.03 ± 0.25
	15	1.97 ± 0.21	3.13 ± 0.50	3.63 ± 0.31
S3B	11	24.80 ± 0.63	54.33 ± 3.01	78.00 ± 2.43
	15	24.17 ± 1.05	53.20 ± 7.21	78.53 ± 3.56
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	964.90 ± 0.61	924.20 ± 3.34	887.70 ± 3.41
	15	963.67 ± 1.41	929.90 ± 3.84	888.03 ± 3.81
S6B	11	4.83 ± 0.11	10.03 ± 0.84	13.67 ± 0.31
	15	4.70 ± 0.17	9.33 ± 0.15	13.97 ± 0.85

TABLE A-22. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Rye

Machine: Labofix-2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	4.76 ± 0.56	12.97 ± 1.74	24.90 ± 1.04
	15	6.97 ± 0.31	15.47 ± 0.92	24.17 ± 1.45
S2B	11	1.14 ± 0.14	3.60 ± 0.20	3.67 ± 1.07
	15	1.43 ± 0.31	2.67 ± 0.06	4.10 ± 1.22
S3B	11	27.38 ± 1.10	50.63 ± 1.19	69.40 ± 5.27
	15	24.23 ± 0.40	49.00 ± 1.74	75.30 ± 2.52
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	961.07 ± 1.17	922.93 ± 1.27	887.33 ± 4.78
	15	959.57 ± 1.17	919.73 ± 1.12	882.23 ± 3.57
S6B	11	5.41 ± 0.26	9.77 ± 0.45	14.73 ± 0.51
	15	4.97 ± 0.35	10.50 ± 0.26	14.97 ± 0.42

TABLE A-23. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Rye

Machine: N.S.L.-1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	7.50 ± 0.75	14.47 ± 0.76	16.77 ± 2.01
	15	4.77 ± 2.75	12.97 ± 6.64	4.37 ± 3.58
S2B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S3B	11	0.60 ± 0.10	1.30 ± 0.26	2.83 ± 1.79
	15	1.70 ± 0.56	2.57 ± 0.21	3.47 ± 1.10
S4B	11	974.97 ± 4.39	956.20 ± 1.58	938.40 ± 4.51
	15	976.53 ± 5.63	954.93 ± 3.86	945.17 ± 3.74
S5B	11	9.17 ± 0.91	17.63 ± 0.15	30.27 ± 0.81
	15	12.30 ± 1.20	18.83 ± 2.60	34.87 ± 1.39
S6B	11	4.33 ± 0.06	8.60 ± 0.30	12.33 ± 1.74
	15	4.60 ± 0.85	7.90 ± 1.22	10.57 ± 0.35

TABLE A-24. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Rye

Machine: N.S.L.-2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	15.93 ± 2.99	28.67 ± 3.02	44.17 ± 4.75
	15	16.17 ± 8.01	45.03 ± 5.86	37.38 ± 27.09
S2B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S3B	11	0.00	1.77 ± 0.49	2.10 ± 0.75
	15	1.37 ± 0.21	2.07 ± 0.23	2.80 ± 1.40
S4B	11	973.70 ± 1.90	950.70 ± 1.77	922.87 ± 3.39
	15	964.40 ± 5.30	934.10 ± 4.86	903.13 ± 3.22
S5B	11	7.10 ± 0.53	14.20 ± 1.50	19.47 ± 1.27
	15	13.63 ± 13.31	9.10 ± 1.91	25.03 ± 6.74
S6B	11	2.03 ± 0.06	5.27 ± 0.15	9.50 ± 0.10
	15	3.50 ± 0.26	6.47 ± 0.32	8.37 ± 1.72

TABLE A-25. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Flax Seed

Machine: CD-XT 3 - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	15.90 ± 0.36	31.03 ± 0.31	48.30 ± 1.47
	15	16.80 ± 0.62	32.43 ± 0.47	34.83 ± 1.11
S2B	11	2.60 ± 0.26	4.43 ± 0.38	6.03 ± 1.07
	15	2.17 ± 0.38	4.03 ± 0.32	6.53 ± 0.35
S3B	11	6.43 ± 0.06	12.63 ± 0.21	15.93 ± 0.40
	15	6.50 ± 0.36	10.87 ± 0.84	16.17 ± 0.29
S4B	11	949.07 ± 0.3	904.53 ± 0.20	866.13 ± 2.98
	15	951.07 ± 0.35	909.23 ± 1.54	864.87 ± 1.62
S5B	11	1.83 ± 0.06	2.03 ± 0.06	5.10 ± 1.44
	15	1.40 ± 0.10	3.17 ± 0.64	4.33 ± 0.55
S6B	11	19.67 ± 0.35	39,73 ± 0.67	58.73 ± 1.31
	15	19.67 ± 0.25	38.83 ± 0.91	70.10 ± 0.44

TABLE A-26. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Flax Seed   Machine: CD-XT 3 - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	17.23 ± 0.25	1.13 ± 0.55	57.73 ± 0.57
	15	17.70 ± 0.36	36.83 ± 0.15	49.60 ± 1.75
S2B	11	2.50 ± 0.36	6.53 ± 0.12	5.83 ± 0.31
	15	1.93 ± 0.21	3.80 ± 0.26	6.73 ± 0.12
S3B	11	3.93 ± 3.18	12.10 ± 0.20	16.23 ± 0.40
	15	7.73 ± 0.12	11.63 ± 0.32	16.63 ± 0.38
S4B	11	948.23 ± 0.87	914.17 ± 2.30	862.00 ± 0.94
	15	946.60 ± 0.35	907.70 ± 0.50	858.57 ± 0.50
S5B	11	1.13 ± 0.21	2.57 ± 0.81	3.00 ± 0.62
	15	1.17 ± 0.21	1.20 ± 0.26	2.97 ± 0.32
S6B	11	18.87 ± 0.15	56.80 ± 2.00	50.83 ± 0.90
	15	17.43 ± 0.40	32.40 ± 0.36	59.33 ± 1.01

TABLE A-27. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Flax Seed   Machine: Labofix - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	19.43 ± 1.21	42.67 ± 1.65	73.80 ± 1.00
	15	21.80 ± 0.20	46.40 ± 0.40	75.23 ± 0.76
S2B	11	3.30 ± 1.76	2.03 ± 0.15	3.33 ± 0.38
	15	0.97 ± 0.45	2.27 ± 0.21	2.70 ± 0.17
S3B	11	19.13 ± 1.54	32.53 ± 2.05	42.67 ± 0.68
	15	13.67 ± 0.55	27.17 ± 0.45	39.37 ± 0.47
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	949.87 ± 3.45	906.60 ± 2.65	865.37 ± 1.00
	15	954.60 ± 0.71	909.97 ± 0.87	866.93 ± 2.15
S6B	11	4.90 ± 1.04	8.40 ± 2.19	11.30 ± 0.44
	15	5.53 ± 0.70	10.27 ± 0.86	11.57 ± 0.21

TABLE A-28. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Flax Seed

Machine: Labofix - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	22.90 ± 0.36	54.30 ± 0.46	75.57 ± 2.66
	15	25.43 ± 0.83	53.60 ± 1.04	86.57 ± 1.00
S2B	11	2.53 ± 0.70	2.63 ± 0.31	14.23 ± 11.05
	15	1.07 ± 0.15	2.33 ± 0.25	2.57 ± 0.59
S3B	11	20.57 ± 1.40	32.60 ± 0.17	44.83 ± 1.07
	15	17.27 ± 0.60	29.13 ± 0.32	42.13 ± 0.74
S4B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S5B	11	946.80 ± 0.35	900.63 ± 1.94	854.93 ± 7.87
	15	948.93 ± 0.87	904.13 ± 0.35	857.57 ± 1.37
S6B	11	3.67 ± 0.25	4.77 ± 0.35	6.80 ± 0.44
	15	5.07 ± 0.75	7.83 ± 0.29	8.23 ± 0.55

TABLE A-29. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Flax Seed Machine: N.S.L. - 1

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.10 ± 0.10	0.13 ± 0.12	0.00
	15	0.00	0.00	0.00
S2B	11	0.00	0.07 ± 0.12	0.00
	15	0.00	0.00	0.00
S3B	11	1.53 ± 0.21	2.73 ± 1.04	2.47 ± 0.50
	15	0.97 ± 0.29	2.07 ± 0.12	4.33 ± 0.29
S4B	11	966.53 ± 5.65	952.03 ± 7.45	906.70 ± 24.65
	15	916.63 ± 75.15	938.67 ± 2.42	927.87 ± 1.27
S5B	11	10.90 ± 1.04	28.10 ± 2.80	35.90 ± 4.88
	15	9.10 ± 0.87	23.33 ± 2.61	49.07 ± 2.73
S6B	11	16.80 ± 2.96	10.97 ± 9.32	27.57 ± 19.37
	15	16.50 ± 0.26	21.73 ± 7.57	12.00 ± 0.92

TABLE A-30. Means ± Standard Deviations of Different Fractions Removed (g) Resulting from Impurity Levels of 5%, 10%, and 15%

Grain Type: Flax Seed

Machine: N.S.L. - 2

Fraction	Moisture Content (%)	Impurity level (%)		
		5	10	15
S1B	11	0.00	0.00	0.00
	15	0.00	0.00	0.00
S2B	11	0.00	0.03 ± 0.06	0.00
	15	0.00	0.00	0.00
S3B	11	2.20 ± 1.21	1.43 ± 0.31	2.60 ± 0.26
	15	0.67 ± 0.12	1.13 ± 0.25	1.93 ± 0.15
S4B	11	965.17 ± 4.97	899.13 ± 49.49	901.17 ± 6.84
	15	965.60 ± 0.50	936.47 ± 4.12	916.70 ± 2.67
S5B	11	11.70 ± 1.49	19.30 ± 0.70	34.30 ± 1.70
	15	11.33 ± 0.10	18.80 ± 1.65	26.30 ± 0.95
S6B	11	18.43 ± 5.20	39.77 ± 6.99	46.60 ± 2.46
	15	16.43 ± 0.72	37.10 ± 5.16	50.63 ± 1.53

TABLE A-31A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: HRS Wheat   Machine: CD-XT 3-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	16.80 19.00 19.20	17.50 18.20 17.50	14.80 15.00 15.87
	18.33 ±1.33	17.73 ±0.40	15.22
15%	18.00 13.00 16.20	14.10 14.80 14.90	15.13 15.13 15.33
	15.73 ±2.53	14.60 ±0.44	15.20 ±0.12

TABLE A-31B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: HRS Wheat   Machine: CD-XT 3-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	40.00 50.00 50.00	97.50 77.50 87.50	88.33 85.00 88.33
		46.67 ±5.77	87.50 ±10.00	87.22 ±1.92
	15%	120.00 100.00 105.00	95.00 87.50 82.50	101.67 93.33 100.00
		108.33 ±10.41	88.33 ±6.29	98.33 ±4.41
η_F	11%	80.00 95.00 80.00	87.50 93.75 90.00	91.67 91.67 98.33
		85.00 ±8.66	90.42 ±3.15	93.89 ±3.85
	15%	105.00 52.50 107.50	96.25 97.50 101.25	95.83 98.33 95.83
		88.33 ±31.06	98.33 ±2.60	96.67 ±1.44
η_B	11%	10.00 10.68 12.27	7.50 8.64 7.73	4.47 4.85 5.08
		10.98 ±1.17	7.95 ±0.60	4.80 ±0.31
	15%	5.45 5.45 3.86	2.95 3.98 3.98	3.86 4.02 4.77
		4.92 ±0.92	3.64 ±0.59	4.02 ±0.17

TABLE A-32A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: HRS Wheat Machine: CD-XT 3-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	17.20 17.00 17.20	16.60 17.40 17.20	15.13 15.87 15.73
	17.23 ±0.12	17.07 ±0.42	15.58 ±0.34
15%	15.60 15.20 14.40	15.20 14.40 14.70	14.53 13.93 14.13
	15.07 ±0.61	14.77 ±0.40	14.20 ±0.31

TABLE A-32B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: HRS Wheat Machine: CD-XT 3-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	50.00 50.00 45.00	77.50 65.00 62.50	85.00 83.33 86.67
		48.33 ±2.89	68.33 ±8.04	85.00 ±1.67
	15%	90.00 85.00 85.00	100.00 87.50 87.50	88.33 83.33 83.33
		86.67 ±2.89	91.67 ±7.22	85.00 ±2.89
η_F	11%	90.00 85.00 80.00	92.50 95.00 92.50	91.67 95.83 93.33
		85.00 ±5.00	93.33 ±1.44	93.61 ±2.10
	15%	107.50 107.50 100.00	100.00 96.25 100.00	97.50 96.67 100.00
		105.00 ±4.33	98.75 ±2.17	98.06 ±1.73
η_B	11%	9.09 9.32 10.23	6.93 8.18 8.30	5.00 5.53 5.45
		9.55 ±0.60	7.80 ±0.76	5.33 ±0.29
	15%	3.86 3.64 3.41	3.64 3.64 3.64	3.64 3.26 3.18
		3.64 ±0.23	3.64 ±0.00	3.36 ±0.24

TABLE A-33A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: HRS Wheat Machine: Labofix-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	84.80	87.00	92.47
	90.20	92.90	90.73
	86.00	91.80	93.53
	87.00 ±2.84	90.57 ±3.14	92.24 ±1.41
15%	103.60	80.10	86.53
	94.00	84.50	84.93
	93.00	81.30	85.47
	96.87 ±5.85	81.96 ±2.27	85.64 ±0.81

TABLE A-33B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: HRS Wheat Machine: Labofix-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00	100.00	100.00
		100.00	100.00	100.00
		100.00	100.00	100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00	100.00	100.00
		100.00	100.00	100.00
		100.00	100.00	100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	67.50	63.75	60.00
		80.00	80.00	59.17
		67.50	62.50	69.17
		71.67 ±7.22	68.75 ±9.76	62.78 ±5.55
	15%	65.00	85.00	60.83
		72.50	66.25	55.00
		72.50	66.25	70.00
		70.00 ±4.33	72.50 ±10.83	61.94 ±7.56
η_B	11%	85.70	88.50	95.10
		90.70	93.80	93.20
		87.00	94.10	95.50
		87.80 ±2.59	92.13 ±3.15	94.60 ±1.23
	15%	107.30	78.80	88.30
		95.70	85.50	87.00
		94.50	81.80	86.20
		99.17 ±7.07	82.03 ±3.36	87.17 ±1.06

TABLE A-34A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: HRS Wheat Machine: Labofix-2

Moisture Content (W.B.) \ Impurity level	5%	10%	15%
11%	88.40 93.00 90.00	90.70 92.10 92.30	89.13 92.47 91.40
	90.46 ±2.34	91.70 ±0.87	91.00 ±1.70
15%	97.40 99.00 95.00	93.60 89.80 87.00	89.67 90.20 88.93
	97.13 ±2.01	90.13 ±3.31	89.60 ±0.64

TABLE A-34B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: HRS Wheat Machine: Labofix-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	60.00 70.00 60.00	60.00 70.00 80.00	47.50 66.67 58.33
		63.33 ±5.77	70.00 ±10.00	57.50 ±9.61
	15%	60.00 77.50 82.50	58.75 61.25 48.75	52.50 67.50 53.33
		73.33 ±11.81	56.25 ±6.61	57.78 ±8.43
η_B	11%	90.50 94.80 92.30	93.10 93.80 93.10	92.40 94.50 94.0
		92.53 ±2.16	93.33 ±0.40	93.63 ±1.10
	15%	100.7 100.9 95.90	96.50 91.90 89.90	92.60 91.80 91.70
		99.17 ±2.83	92.77 ±3.38	92.03 ±0.49

TABLE A-35A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: HRS Wheat Machine: N.S.L.-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	24.60 31.80 25.00	35.90 31.90 37.20	35.20 28.20 35.47
	27.13 ±4.05	35.00 ±2.76	32.96 ±4.12
15%	33.40 30.80 34.80	32.70 37.00 36.70	34.00 29.40 32.00
	33.00 ±2.03	35.47 ±2.40	31.80 ±2.31

TABLE A-35B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: HRS Wheat Machine: N.S.L.-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	2.50 25.00 5.00	37.50 40.00 65.00	55.00 19.17 81.67
		10.83 ±12.33	47.50 ±15.21	51.94 ±31.36
	15%	62.50 57.50 62.50	57.50 53.57 62.50	73.33 52.50 45.83
		60.83 ±2.89	57.92 ±4.39	57.22 ±14.35
η_B	11%	23.20 29.30 23.40	32.80 28.10 31.80	30.50 25.80 28.30
		25.30 ±3.47	30.90 ±2.48	28.20 ±2.35
	15%	27.70 25.20 29.30	27.40 32.60 31.50	27.40 24.10 27.70
		27.40 ±2.07	30.50 ±2.74	26.40 ±2.0

TABLE A-36A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: HRS Wheat Machine: N.S.L.-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	51.60	48.70	37.67
	57.80	47.30	50.60
	58.80	51.00	57.67
	56.07 ±3.90	49.00 ±1.87	48.64 ±10.14
15%	56.20	53.30	46.93
	56.60	54.90	46.20
	57.80	47.20	43.40
	56.87 ±0.83	51.80 ±4.06	45.51 ±1.86

TABLE A-36B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: HRS Wheat Machine: N.S.L.-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00	100.00	100.00
		100.00	100.00	100.00
		100.00	100.00	100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ± 0.0
	15%	100.00	100.00	100.00
		100.00	100.00	100.00
		100.00	100.00	100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	2.50	48.75	53.33
		17.50	51.25	60.83
		0.00	47.50	72.50
		6.67 ±9.46	49.17 ±1.91	62.22 ±9.66
	15%	72.50	62.50	55.00
		45.00	58.75	61.67
		97.50	62.50	66.67
		71.67 ±26.26	61.25 ±2.17	61.11 ±5.85
η_B	11%	53.90	62.50	33.40
		59.50	44.50	47.40
		62.30	49.10	54.40
		58.57 ±4.28	46.67 ±2.31	45.57 ±10.69
	15%	52.70	50.30	43.80
		55.70	52.50	42.30
		52.30	43.40	38.70
		53.57 ±1.86	48.73 ±4.75	41.60 ±2.62

TABLE A-37A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: White Wheat Machine: CD-XT 3 - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	27.26 19.56 14.70	15.06 15.35 14.97	15.85 19.77 16.56
	20.51 ± 6.33	15.13 ± 0.20	17.40 ± 2.09
15%	16.72 17.04 18.62	17.56 13.58 12.90	19.11 21.12 20.97
	17.46 ± 1.02	14.68 ± 2.52	20.40 ± 1.12

TABLE A-37B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: White Wheat Machine: CD-XT 3 - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	93.50 65.00 83.50	83.50 63.25 61.75	58.83 71.67 52.17
		80.67 ± 14.46	69.50 ± 12.15	60.89 ± 9.91
	15%	78.00 54.50 67.00	1.75 49.75 60.50	49.83 49.33 61.67
		66.50 ± 11.76	37.33 ± 31.28	53.61 ± 6.98
η_F	11%	106.50 111.25 130.25	100.13 99.63 102.75	90.50 99.58 92.92
		116.00 ± 12.57	100.83 ± 1.68	94.33 ± 4.70
	15%	99.25 101.75 106.25	105.00 95.63 101.25	97.67 92.83 99.33
		102.42 ± 3.55	100.63 ± 4.72	96.61 ± 3.38
η_B	11%	17.05 9.16 1.07	4.22 5.51 4.86	7.11 10.16 8.00
		9.09 ± 7.99	4.86 ± 0.65	8.4
	15%	6.43 7.64 8.45	10.33 4.48 2.70	10.57 13.32 11.99
		7.51 ± 1.02	5.84 ± 3.99	11.96 ± 1.38

TABLE A-38A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: White Wheat

Machine: CD-XT 3 - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	19.52 16.10 6.62	15.57 14.99 10.12	15.29 16.76 15.85
	14.08 ± 6.68	13.56 ± 2.99	15.97 ± 0.74
15%	19.54 17.12 18.10	19.37 18.40 17.92	15.15 18.54 17.91
	18.25 ± 1.22	18.56 ± 0.74	17.20 ± 1.80

TABLE A-38B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: White Wheat

Machine: CD-XT 3 - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	30.50 25.00 5.50	69.00 45.75 51.25	41.33 55.33 69.50
		20.33 ± 13.14	55.33 ± 12.15	55.39 ± 14.08
	15%	76.00 65.00 52.50	78.25 88.50 67.50	81.17 93.67 95.33
		64.50 ± 11.76	78.08 ± 10.50	90.06 ± 7.74
η_F	11%	133.50 126.00 20.00	99.88 93.63 87.38	96.50 101.25 102.00
		93.17 ± 63.48	93.63 ± 6.25	99.92 ± 2.98
	15%	95.75 94.00 102.25	91.13 83.88 80.88	92.92 94.25 97.75
		97.33 ± 4.35	85.29 ± 5.27	94.97 ± 2.50
η_B	11%	8.66 5.70 5.45	5.48 6.44 1.23	6.72 7.33 5.58
		6.61 ± 1.78	4.38 ± 2.77	6.54 ± 0.88
	15%	10.05 7.95 8.89	10.17 9.26 9.94	5.08 8.24 7.13
		8.96 ± 1.05	9.79 ± 0.47	6.82 ± 1.61

TABLE A-39A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: White Wheat Machine: Labofix - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	65.56 65.52 66.38	72.16 68.30 74.85	90.00 90.74 88.56
	65.82 ± 0.48	71.77 ± 3.29	89.77 ± 1.11
15%	99.88 85.64 86.28	79.32 84.27 81.79	93.30 87.07 87.49
	90.60 ± 8.04	81.79 ± 2.47	89.28 ± 3.48

TABLE A-39B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: White Wheat Machine: Labofix - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	48.25 30.75 23.00	47.13 49.88 39.63	74.92 87.50 58.33
		34.00 ± 12.93	45.54 ± 5.31	73.58 ± 14.63
	15%	144.50 42.25 58.50	35.38 25.38 29.88	53.17 25.50 23.75
		81.75 ± 54.95	30.21 ± 5.01	34.14 ± 16.50
η_B	11%	65.70 67.0 68.90	73.20 68.5 76.90	90.90 90.60 90.80
		67.2 ± 1.61	72.87 ± 4.21	90.77 ± 0.15
	15%	95.90 88.90 88.20	82.40 89.00 85.70	96.70 92.10 92.70
		91.0 ± 4.26	85.70 ± 3.30	93.83 ± 2.50

TABLE A-40A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: White Wheat Machine: Labofix - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	72.70 70.24 73.14	84.96 83.58 81.58	84.71 87.43 86.02
	72.03 ± 1.56	83.37 ± 1.70	86.05 ± 1.36
15%	87.70 88.50 90.14	94.38 87.39 88.39	91.17 93.67 91.04
	88.78 ± 1.24	90.05 ± 3.78	91.96 ± 1.48

TABLE A-40B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: White Wheat Machine: Labofix - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	56.25 49.25 52.50	23.63 28.75 38.00	29.42 37.17 30.42
		52.67 ± 3.50	30.13 ± 7.29	32.33 ± 4.22
	15%	37.50 26.50 29.50	23.75 31.13 25.63	32.67 30.00 27.42
		31.17 ± 5.69	26.83 ± 3.83	30.03 ± 2.63
η_B	11%	73.0 70.90 73.90	89.80 87.80 84.70	89.10 91.40 90.50
		72.6 ± 1.54	87.43 ± 2.57	90.33 ± 1.16
	15%	91.60 93.60 95.20	100.60 91.90 93.60	96.10 99.20 96.40
		93.47 ± 1.80	95.37 ± 4.61	97.23 ± 1.71

TABLE A-41A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: White Wheat Machine: N.S.L. - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	39.10 36.56 40.34	38.73 39.11 37.31	29.22 36.08 33.43
	38.67 ± 1.93	38.38 ± 0.95	32.91 ± 3.46
15%	73.34 58.04 67.42	36.99 43.79 41.55	36.77 36.20 37.75
	66.27 ± 7.71	40.78 ± 3.47	36.91 ± 0.79

TABLE A-41B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: White Wheat Machine: N.S.L. - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	155.50 180.50 190.25	19.00 16.50 12.38	16.75 33.92 33.50
		175.42 ± 17.92	15.96 ± 3.35	28.06 ± 9.79
	15%	547.25 435.25 473.50	180.00 173.13 145.75	74.17 107.67 106.42
		485.33 ± 56.93	166.29 ± 18.12	96.08 ± 18.99
η_B	11%	25.70 20.70 23.90	37.70 38.40 36.70	27.10 33.40 30.50
		23.43 ± 2.53	37.60 ± 0.85	30.33 ± 3.15
	15%	29.10 22.0 29.10	21.10 29.40 29.40	30.50 26.80 28.70
		26.73 ± 4.10	26.63 ± 4.79	28.67 ± 1.85

TABLE A-42A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: White Wheat Machine: N.S.L. - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	37.94 33.72 39.20	45.40 24.16 34.54	32.90 30.44 29.62
	36.95 ± 2.87	34.70 ± 10.62	30.99 ± 1.71
15%	51.74 41.74 54.16	38.87 52.79 38.25	31.73 32.51 32.07
	49.21 ± 6.58	43.30 ± 8.22	32.10 ± 0.39

TABLE A-42B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: White Wheat Machine: N.S.L. - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	49.50 61.50 48.00	11.88 17.00 61.25	43.58 52.42 53.08
		53.00 ± 7.40	30.04 ± 27.15	49.69 ± 5.30
	15%	236.75 109.75 319.25	78.88 131.38 119.88	38.92 60.17 74.75
		221.92 ± 105.53	110.04 ± 27.60	57.94 ± 18.02
η_B	11%	34.0 28.20 35.70	46.00 21.40 29.10	28.90 25.20 24.30
		32.67 ± 3.95	32.17 ± 12.58	26.13 ± 2.44
	15%	32.70 33.00 28.00	32.50 43.50 28.00	28.0 27.0 25.10
		31.23 ± 2.80	34.67 ± 7.97	26.70 ± 1.47

TABLE A-43A. Overall Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Grain Sorghum Machine: CD-XT 3 - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	67.80 70.40 65.80	60.30 54.36 59.00	60.73 62.40 62.20
	68.00 ± 2.31	57.87 ± 3.12	61.78 ± 0.91
15%	65.20 68.60 67.20	61.30 63.90 61.90	64.53 63.93 65.80
	67.00 ± 1.71	62.97 ± 1.36	64.76 ± 0.95

TABLE A-43B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Grain Sorghum Machine: CD-XT 3 - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
η_F	11%	190.00 110.00 90.00	100.00 ± 0.00 95.00 ± 0.00 100.00 ± 0.00	73.33 106.67 110.00
		130.00 ± 52.92	98.33 ± 2.89	96.67 ± 20.28
	15%	90.00 50.00 130.00	90.00 90.00 105.00	86.67 86.67 103.33
		90.00 ± 40.00	95.00 ± 8.66	92.22 ± 9.62
η_B	11%	69.57 74.13 69.57	63.37 56.96 61.96	64.42 65.51 65.22
		71.09 ± 2.64	60.76 ± 3.37	65.05 ± 0.56
	15%	68.91 73.48 70.22	64.67 67.50 65.00	68.22 67.21 69.28
		70.87 ± 2.35	65.72 ± 1.55	68.38 ± 0.84

TABLE A-44A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Grain Sorghum — Machine: CD-XT 3 - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	69.80 68.20 74.20	69.60 60.20 64.00	62.07 62.47 62.53
	70.73 ± 3.11	64.60 ± 4.73	62.36 ± 0.25
15%	69.20 60.00 58.20	70.00 69.30 69.90	72.47 70.67 71.40
	62.47 ± 5.90	69.73 ± 0.38	71.51 ± 0.91

TABLE A-44B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Grain Sorghum — Machine: CD-XT 3 - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	15%	0.00 0.00 0.00	0.00 0.00 0.00	0.00 0.00 0.00
		0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
η_F	11%	110.00 110.00 100.00	95.00 80.00 95.00	93.33 83.33 86.67
		106.67 ± 5.77	90.00 ± 8.66	87.78 ± 5.09
	15%	70.00 100.00 130.00	90.00 80.00 85.00	96.67 93.00 76.67
		100.00 ± 30.00	85.00 ± 5.00	88.89 ± 10.72
η_B	11%	73.48 71.74 78.48	73.59 67.70 67.50	65.43 66.09 66.09
		74.57 ± 3.50	68.26 ± 4.99	65.87 ± 0.38
	15%	73.70 63.04 60.43	74.13 73.59 74.13	76.67 68.80 75.59
		65.72 ± 7.03	73.95 ± 0.31	73.69 ± 4.26

TABLE A-45A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Grain Sorghum Machine: Labofix - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	86.80 88.60 87.20	77.00 79.30 78.00	80.80 79.93 84.00
	87.52 ± 0.94	78.11 ± 1.15	81.60 ± 2.13
15%	75.00 74.40 81.40	78.20 73.80 76.40	78.53 75.27 77.33
	76.93 ± 3.88	76.13 ± 2.21	77.04 ± 1.65

TABLE A-45B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Grain Sorghum Machine: Labofix - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	90.00 60.00 70.00	95.00 90.00 85.00	110.00 86.67 120.00
		73.33 ± 15.28	90.00 ± 5.00	105.56 ± 17.11
	15%	110.00 110.00 110.00	110.00 120.00 115.00	110.00 106.67 100.00
		110.00 ± 0.00	115.00 ± 5.00	105.56 ± 5.09
η_B	11%	85.90 88.50 86.70	75.10 77.70 76.40	78.90 78.50 82.20
		87.03 ± 1.33	76.40 ± 1.30	74.87 ± 2.03
	15%	72.60 72.00 79.60	76.10 71.10 74.0	76.40 73.0 75.40
		74.73 ± 4.23	73.78 ± 2.51	74.93 ± 1.75

TABLE A-46A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Grain Sorghum Machine: Labofix - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	85.40 81.40 87.20	79.30 78.10 79.10	82.60 76.87 79.93
	84.67 ± 2.97	78.83 ± 0.64	79.86 ± 2.87
15%	82.00 81.20 81.40	76.50 72.90 78.80	73.87 80.33 80.00
	81.53 ± 0.42	76.07 ± 2.97	78.07 ± 3.64

TABLE A-46B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Grain Sorghum Machine: Labofix - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	70.00 100.00 80.00	100.00 85.00 80.00	96.67 100.00 96.67
		83.33 ± 15.28	88.33 ± 10.41	97.78 ± 1.92
	15%	200.00 130.00 120.00	105.00 110.00 110.00	100.00 100.00 106.67
		150.00 ± 43.59	108.33 ± 2.89	102.22 ± 3.85
η_B	11%	84.80 79.80 86.40	77.50 76.50 77.70	81.40 74.90 78.30
		83.70 ± 3.48	77.23 ± 0.64	78.2 ± 3.25
	15%	78.30 78.90 79.30	74.30 70.30 76.70	71.60 78.60 78.10
		78.83 ± 0.50	73.77 ± 3.23	76.1 ± 3.91

TABLE A-47A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Grain Sorghum Machine: N.S.L. - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	64.40 62.80 61.40	58.80 57.60 60.00	57.00 54.27 61.13
	62.87 ± 1.50	58.80 ± 1.20	57.47 ± 3.46
15%	55.00 54.80 55.20	57.40 59.10 58.40	56.80 59.13 60.47
	55.00 ± 0.20	58.30 ± 0.85	58.80 ± 1.86

TABLE A-47B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Grain Sorghum Machine: N.S.L. - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	20.00 30.00 30.00	0.00 0.00 10.00	6.67 10.00 6.67
		26.67 ± 5.77	3.33 ± 5.77	7.78 ± 1.92
	15%	100.00 40.00 100.00	15.00 45.00 10.00	16.67 20.00 163.33
		80.00 ± 34.64	23.33 ± 18.93	66.67 ± 83.73
η_B	11%	63.0 61.10 59.60	57.40 56.10 58.50	55.30 52.20 59.80
		61.23 ± 1.70	57.33 ± 1.20	55.77 ± 3.82
	15%	51.10 52.20 51.30	55.50 56.70 56.70	54.90 57.30 55.70
		51.53 ± 0.59	56.30 ± 0.69	55.97 ± 1.22

TABLE A-48A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Grain Sorghum Machine: N.S.L. - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	57.00 60.80 59.80	57.50 57.60 56.50	60.27 64.67 63.53
	59.20 ± 1.97	57.20 ± 0.61	62.82 ± 2.28
15%	57.20 58.80 54.00	59.10 57.80 59.90	53.60 53.60 54.60
	56.67 ± 2.44	58.93 ± 1.06	53.93 ± 0.58

TABLE A-48B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Grain Sorghum Machine: N.S.L. - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	0.00 0.00 30.00	0.00 40.00 0.00	0.00 16.67 103.33
		10.00 ± 17.32	13.33 ± 23.09	40.00 ± 55.48
	15%	20.00 160.00 10.00	10.00 0.00 140.00	0.00 70.00 43.33
		63.33 ± 83.86	50.00 ± 78.10	37.78 ± 35.33
η_B	11%	55.40 59.60 57.80	56.0 55.20 54.90	59.0 63.40 60.30
		57.6 ± 2.11	55.37 ± 0.57	60.90 ± 2.26
	15%	55.20 53.90 52.0	57.50 56.30 55.50	51.70 50.20 51.90
		53.7 ± 1.61	56.43 ± 1.01	51.27 ± 0.93

TABLE A-49A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Rye Machine: CD-XT.3-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	14.54 14.66 14.88	14.20 15.00 15.20	14.93 15.53 15.47
	14.69 ±0.17	14.80 ±0.53	15.31 ±0.33
15%	17.60 18.40 18.40	18.50 18.10 18.00	17.26 17.47 17.47
	18.13 ±0.46	18.20 ±0.26	17.40 ±0.12

TABLE A-49B. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Rye Machine: CD-XT.3-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	38.50 37.00 36.00	40.00 40.00 37.50	63.33 60.00 60.00
		37.17 ±1.26	39.17 ±1.44	61.11 ±1.92
	15%	100.00 110.00 110.00	112.50 110.00 92.50	85.00 70.00 78.33
		106.67 ±5.77	105.00 ±10.90	77.78 ±7.52
η_F	11%	85.00 87.75 86.25	71.25 83.75 83.75	86.66 85.83 85.00
		86.33 ±1.38	79.58 ±7.22	85.83 ±0.83
	15%	122.50 100.00 102.50	96.26 73.75 110.00	42.50 35.00 39.17
		108.33 ±12.33	93.34 ±18.30	38.89 ±3.76
η_B	11%	7.05 7.00 7.43	7.84 7.61 7.96	6.06 7.12 7.12
		7.16 ±0.24	7.80 ±0.18	6.77 ±0.61
	15%	4.32 6.82 6.59	7.16 7.05 6.25	7.80 8.56 7.88
		5.91 ±1.38	6.65 ±0.56	8.08 ±0.42

TABLE A-50A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Rye Machine: CD-XT.3-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	19.06 17.12 16.30	16.30 15.20 14.60	15.33 14.93 15.07
	17.49 ±1.42	15.37 ±0.86	15.11 ±0.20
15%	24.40 20.80 22.20	18.10 18.10 16.90	22.10 22.03 16.33
	22.47 ±1.81	17.70 ±0.69	20.16 ±3.31

TABLE A-50B. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Rye Machine: CD-XT.3-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	30.50 38.00 37.00	75.00 45.00 40.00	58.33 66.67 68.33
		35.17 ±4.07	53.33 ±18.93	64.44 ±5.36
	15%	115.00 100.00 90.00	92.50 97.50 92.50	91.67 88.33 90.00
		101.67 ±12.58	94.17 ±2.89	90.00 ±1.67
η_F	11%	96.25 81.00 92.00	81.25 81.25 85.00	92.50 90.00 87.50
		89.75 ±7.87	82.50 ±2.17	90.00 ±2.50
	15%	310.00 265.00 310.00	102.50 101.25 92.50	95.00 96.67 93.33
		295.00 ±25.98	98.75 ±5.45	95.00 ±1.67
η_B	11%	11.52 10.36 8.48	7.73 7.84 7.05	6.36 5.08 5.15
		10.12 ±1.54	7.54 ±0.43	5.53 ±0.72
	15%	8.41 7.05 7.05	6.82 6.93 6.59	5.90 5.83 5.98
		7.50 ±0.79	6.78 ±0.17	5.90 ±0.08

TABLE A-51A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Rye Machine: Labofix-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	69.48 68.48 65.44	71.80 74.60 79.30	72.87 74.07 77.80
	67.80 ±2.10	75.23 ±3.79	74.91 ±2.57
15%	69.80 74.60 71.80	81.50 68.90 72.50	69.93 72.47 75.80
	72.07 ±2.41	74.30 ±6.49	72.73 ±2.94

TABLE A-51B. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Rye Machine: Labofix-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	22.00 20.50 22.00	21.25 35.00 42.50	31.67 33.33 35.83
		21.50 ±0.87	32.92 ±10.78	33.61 ±2.10
	15%	47.50 45.00 55.00	45.00 40.00 32.50	32.50 30.83 27.50
		49.17 ±5.20	39.17 ±6.29	30.28 ±2.55
η_B	11%	72.40 71.40 67.80	75.10 77.0 81.70	75.40 76.60 80.60
		70.53 ±2.42	77.93 ±3.40	77.53 ±2.72
	15%	70.50 76.10 72.0	86.30 70.10 74.90	72.0 75.0 79.10
		72.87 ±2.90	77.1 ±8.32	75.37 ±3.56

TABLE A-52A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Rye Machine: Labofix-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	78.44 75.36 78.36	75.80 76.10 79.00	78.33 74.67 72.40
	77.39 ±1.76	76.97 ±1.77	75.13 ±2.99
15%	74.60 76.60 74.40	77.80 76.40 78.70	80.46 78.26 78.33
	75.20 ±1.22	77.63 ±1.16	79.02 ±1.25

TABLE A-52B. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Rye Machine: Labofix-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	28.00 25.50 32.25	45.00 42.50 47.50	32.50 38.33 20.83
		28.58 ±3.41	45.00 ±2.50	30.56 ±8.91
	15%	37.50 42.50 27.50	33.75 33.75 32.50	45.83 29.17 27.50
		35.83 ±7.64	33.33 ±0.72	34.17 ±10.14
η_B	11%	82.0 78.80 81.60	77.50 78.10 80.90	81.50 76.80 75.80
		80.80 ±1.74	78.33 ±1.81	78.03 ±3.04
	15%	76.80 78.60 77.50	80.80 79.20 81.90	82.70 81.70 82.0
		77.63 ±0.91	80.63 ±1.36	82.13 ±0.51

TABLE A-53A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Rye   Machine: N.S.L.-1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	42.2 47.0 40.4	42.4 42.9 32.1	39.4 39.7 45.3
	43.20 ±3.41	41.17 ±4.95	41.47 ±3.32
15%	50.40 49.80 40.00	36.70 45.00 45.10	34.73 33.46 38.33
	46.73 ±5.84	42.43 ±4.97	35.51 ±2.52

TABLE A-53B. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Rye   Machine: N.S.L.-1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 -	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	15.00 17.50 10.00	18.75 17.50 12.50	15.00 15.00 40.83
		14.17 ±3.82	15.63 ±4.42	23.61 ±14.91
	15%	55.00 45.00 27.50	35.00 30.00 31.25	21.67 25.83 39.17
		41.25 ±19.45	32.08 ±2.60	28.89 ±9.14
η_B	11%	42.0 47.30 40.20	41.90 42.60 40.60	38.90 39.20 43.20
		43.17 ±3.69	41.70 ±1.01	40.43 ±2.40
	15%	47.70 56.60 38.40	34.0 43.90 43.90	33.0 31.10 35.50
		47.57 ±9.10	40.60 ±5.72	33.20 ±2.21

TABLE A-54A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Rye Machine: N.S.L.-2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	44.40 52.40 53.60	48.70 51.90 49.10	52.13 49.80 48.53
	50.13 ±5.00	49.90 ±1.74	50.15 ±1.83
15%	81.60 61.60 64.80	63.90 65.90 58.20	23.29 63.80 60.07
	69.33 ±10.74	62.67 ±4.00	49.05 ±22.39

TABLE A-54B. Removal Efficiencies of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Rye Machine: N.S.L.-2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.67 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ±0.0	100.00 ±0.0	100.00 ±0.0
η_F	11%	0	15.00 26.25 25.00	10.83 18.33 23.33
			22.08 ±6.17	17.50 ±6.29
	15%	40.00 30.00 32.50	27.50 27.50 22.50	10.00 31.67 28.33
		34.17 ±5.20	25.83 ±2.89	23.33 ±11.67
η_B	11%	45.90 55.0 56.40	49.40 52.0 49.0	53.70 50.40 48.50
		52.43 ±5.70	50.13 ±1.63	50.87 ±2.63
	15%	84.50 62.70 66.10	65.60 67.80 59.50	21.0 65.10 61.10
		71.10 ±11.73	64.30 ±4.30	49.07 ±24.39

TABLE A-55A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Flax Seed Machine: CD-XT 3 - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	92.80 92.20 93.60	89.50 89.70 90.40	88.53 88.87 90.80
	92.87 ± 0.70	89.87 ± 0.47	89.40 ± 1.22
15%	91.60 92.40 95.20	87.40 90.80 89.80	88.40 89.13 86.40
	93.07 ± 1.89	89.33 ± 1.75	87.98 ± 1.41

TABLE A-55B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Flax Seed Machine: CD-XT 3 - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	86.67 87.78 90.56	85.28 86.94 86.39	86.30 91.11 90.93
		88.33 ± 2.00	86.20 ± 0.85	89.44 ± 2.73
	15%	90.56 92.22 97.22	91.11 90.56 88.61	64.26 66.67 62.59
		93.33 ± 3.47	90.09 ± 1.31	64.51 ± 2.05
η_F	11%	125.00 120.00 145.00	115.00 117.50 100.00	110.00 80.00 111.67
		130.00 ± 13.23	110.83 ± 9.46	100.56 ± 17.82
	15%	100.00 95.00 130.00	95.00 110.00 97.50	115.00 108.33 103.33
		108.33 ± 18.93	100.83 ± 8.04	108.89 ± 5.85
η_B	11%	94.33 93.00 92.00	90.33 89.50 92.17	88.44 88.11 89.63
		93.11 ± 1.17	90.67 ± 1.36	88.63 ± 0.63
	15%	91.67 92.33 91.67	84.67 89.67 90.00	101.11 101.33 99.56
		91.89 ± 0.38	88.11 ± 2.99	100.67 ± 0.97

TABLE A-56A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Flax Seed Machine: CD-XT 3 - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	93.60 84.40 84.00	82.20 79.30 75.90	88.40 89.13 89.73
	87.33 ± 5.43	79.13 ± 3.15	89.09 ± 0.67
15%	95.80 96.40 95.60	85.30 86.30 86.00	91.13 90.07 89.33
	95.93 ± 0.42	85.87 ± 0.51	90.18 ± 0.90

TABLE A-56B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Flax Seed Machine: CD-XT 3 - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	95.56 97.22 94.44	4.72 3.06 1.67	107.22 107.78 105.74
		95.74 ± 1.40	3.15 ± 1.53	106.91 ± 1.05
	15%	111.11 107.22 110.00	102.22 102.78 101.94	95.19 91.67 88.70
		109.44 ± 2.00	102.31 ± 0.42	91.85 ± 3.24
η_F	11%	105.00 130.00 140.00	160.00 165.00 165.00	91.67 101.67 98.33
		125.00 ± 18.03	163.33 ± 2.89	97.22 ± 5.09
	15%	100.00 105.00 85.00	90.00 102.50 92.50	110.00 113.33 113.33
		96.67 ± 10.41	95.00 ± 6.61	112.22 ± 1.92
η_B	11%	91.67 73.67 74.00	123.50 119.33 114.50	76.89 77.11 79.56
		79.78 ± 10.30	119.11 ± 4.50	77.85 ± 1.48
	15%	86.33 89.33 87.67	74.83 75.33 76.00	87.44 87.56 88.11
		87.78 ± 1.50	75.39 ± 0.58	87.70 ± 0.35

TABLE A-57A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Flax Seed

Machine: Labofix - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	90.20 95.60 94.80	85.40 87.50 84.00	87.13 88.07 87.00
	93.53 ± 2.91	85.63 ± 1.76	87.40 ± 0.58
15%	85.80 82.40 83.60	85.20 86.70 86.40	86.00 85.53 86.20
	83.93 ± 1.72	86.10 ± 0.79	85.91 ± 0.34

TABLE A-57B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Flax Seed

Machine: Labofix - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	130.00 265.00 100.00	50.00 47.50 55.00	58.33 60.00 48.33
		165.00 ± 87.89	50.83 ± 3.82	55.56 ± 6.31
	15%	70.00 25.00 50.00	52.50 55.00 62.50	46.67 41.67 46.67
		48.33 ± 22.55	56.67 ± 5.20	45.00 ± 2.89
η_B	11%	81.70 81.70 91.30	79.0 82.70 76.30	81.30 82.80 81.80
		84.9 ± 5.54	79.33 ± 3.21	81.97 ± 0.76
	15%	78.30 75.70 76.00	78.50 80.80 79.80	80.20 79.80 80.60
		76.67 ± 1.42	79.70 ± 1.15	80.20 ± 0.4

TABLE A-58A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Flax Seed Machine: Labofix - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	97.60 100.20 100.20	94.40 94.00 94.50	88.87 99.13 94.86
	99.33 ± 1.50	94.30 ± 0.26	94.29 ± 5.15
15%	93.80 97.40 101.80	92.40 92.80 93.20	91.93 94.73 92.33
	97.67 ± 4.01	92.80 ± 0.40	93.00 ± 1.51

TABLE A-58B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Flax Seed Machine: Labofix - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
	15%	100.00 100.00 100.00	100.00 100.00 100.00	100.00 100.00 100.00
		100.00 ± 0.0	100.00 ± 0.0	100.00 ± 0.0
η_F	11%	130.00 160.00 90.00	72.50 57.50 67.50	55.00 423.33 233.33
		126.67 ± 35.12	65.83 ± 7.64	237.22 ± 184.19
	15%	45.00 60.00 55.00	62.50 55.00 50.00	46.67 50.00 31.67
		53.33 ± 7.64	55.83 ± 6.29	42.78 ± 9.77
η_B	11%	94.0 96.30 101.0	92.50 92.80 93.0	84.4 77.0 82.60
		97.10 ± 3.57	92.77 ± 0.25	81.33 ± 3.86
	15%	93.30 98.30 106.0	89.80 91.0 92.0	90.10 94.60 91.80
		99.20 ± 6.40	90.93 ± 1.10	92.17 ± 2.27

TABLE A-59A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates
Grain type: Flax Seed Machine: N.S.L. - 1

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	57.00 64.60 54.40	50.70 40.10 35.20	55.27 40.33 36.27
	58.67 ± 5.30	42.00 ± 7.92	43.96 ± 10.00
15%	52.00 54.00 53.40	52.10 47.20 42.10	42.73 43.00 45.07
	53.13 ± 1.03	47.13 ± 5.00	43.60 ± 1.28

TABLE A-50B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels
Grain type: Flax Seed Machine: N.S.L. - 1

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	82.22 100.0 86.67	60.28 21.11 11.11	91.85 36.85 24.44
		93.89 ± 16.51	30.83 ± 25.99	51.05 ± 35.88
	15%	92.22 92.78 90.00	80.56 61.94 38.61	23.70 22.59 20.37
		91.67 ± 1.47	60.37 ± 21.02	22.22 ± 1.70
η_F	11%	80.00 85.00 65.00	102.50 60.00 47.50	50.00 40.00 33.33
		76.67 ± 10.41	70.00 ± 28.83	41.11 ± 8.39
	15%	65.00 40.00 40.00	50.00 55.00 50.00	75.00 66.67 75.00
		48.33 ± 14.43	51.67 ± 2.89	72.22 ± 4.81
η_B	11%	40.33 42.0 34.33	41.50 50.17 48.83	33.67 42.44 43.56
		38.37 ± 4.05	46.83 ± 4.67	39.89 ± 5.42
	15%	27.00 31.67 32.33	35.17 37.83 43.67	50.00 53.67 57.89
		30.33 ± 2.91	38.89 ± 4.35	54.52 ± 3.04

TABLE A-60A. Overall Removal Efficiencies (%) at Impurity Levels of 5%, 10% and 15% for Three Replicates

Grain type: Flax Seed

Machine: N.S.L. - 2

Impurity level / Moisture Content (W.B.)	5%	10%	15%
11%	64.40 58.20 71.40	67.10 62.40 52.10	54.27 55.20 57.53
	64.67 ± 6.60	60.53 ± 7.67	55.67 ± 1.68
15%	54.80 58.60 57.20	53.30 59.60 58.20	52.67 52.93 52.13
	56.87 ± 1.92	57.03 ± 3.31	52.58 ± 0.41

TABLE A-60B. Removal Efficiencies (%) of Light Material, Foreign Materials, and Broken, Shrunken, Shriveled and Powdered Kernels

Grain type: Flax Seed

Machine: N.S.L. - 2

Removal efficiencies	Moisture content	Impurity levels		
		5%	10%	15%
η_L	11%	100.0 73.89 100.0	100.0 100.0 90.00	85.19 82.41 91.30
		91.3 ± 15.07	96.67 ± 5.77	86.30 ± 4.55
	15%	86.67 93.33 93.89	86.67 100.0 100.0	94.81 95.93 90.56
		91.30 ± 4.02	95.56 ± 7.70	93.77 ± 2.83
η_F	11%	55.00 175.00 100.00	37.50 45.00 27.50	46.67 38.33 45.00
		110.00 ± 60.62	36.67 ± 8.78	43.33 ± 4.41
	15%	30.00 40.00 30.00	35.00 27.50 22.50	35.00 30.00 31.67
		33.33 ± 5.77	28.33 ± 6.29	32.22 ± 2.55
η_B	11%	43.70 41.00 52.30	49.30 41.0 31.00	36.22 40.00 38.11
		45.67 ± 5.90	40.43 ± 9.16	38.11 ± 1.89
	15%	37.33 39.00 37.00	34.50 37.50 35.50	28.56 28.67 30.44
		37.78 ± 1.07	35.83 ± 1.53	29.22 ± 1.06

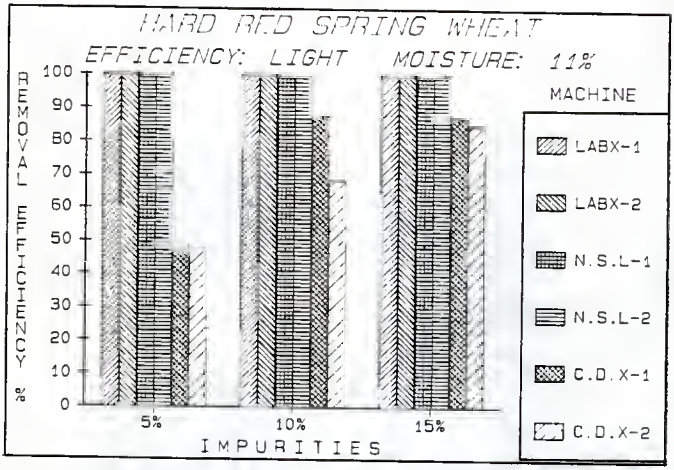

Figure A-1. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Hard Red Spring Wheat at 11% Moisture

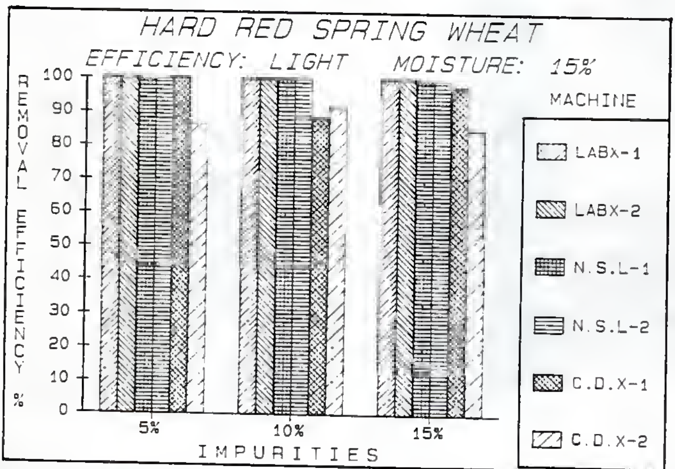

Figure A-2. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Hard Red Spring Wheat at 15% Moisture

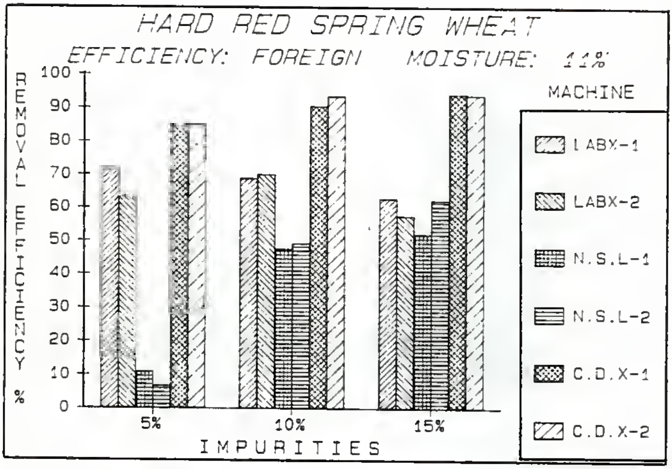

Figure A-3. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Hard Red Spring Wheat at 11% Moisture

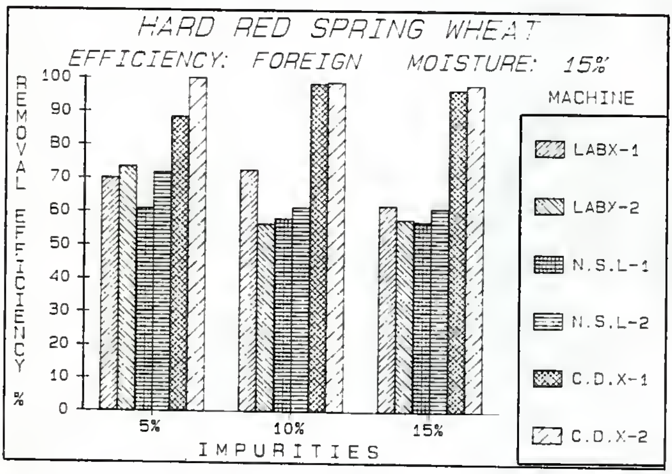

Figure A-4. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Hard Red Spring Wheat at 15% Moisture

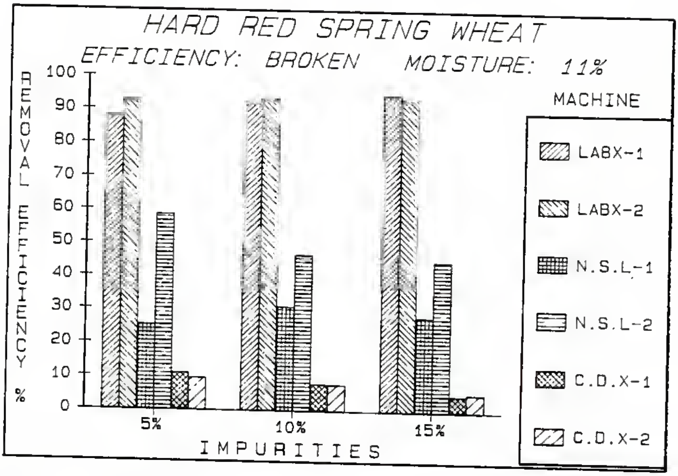

Figure A-5. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Hard Red Spring Wheat at 11% Moisture

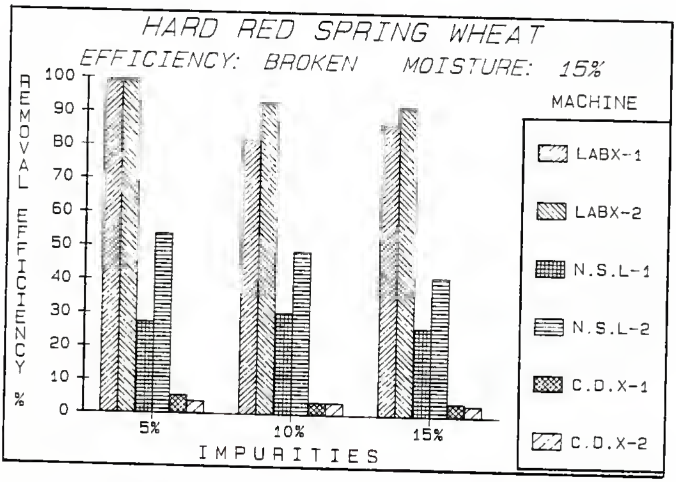

Figure A-6. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Hard Red Spring Wheat at 15% Moisture

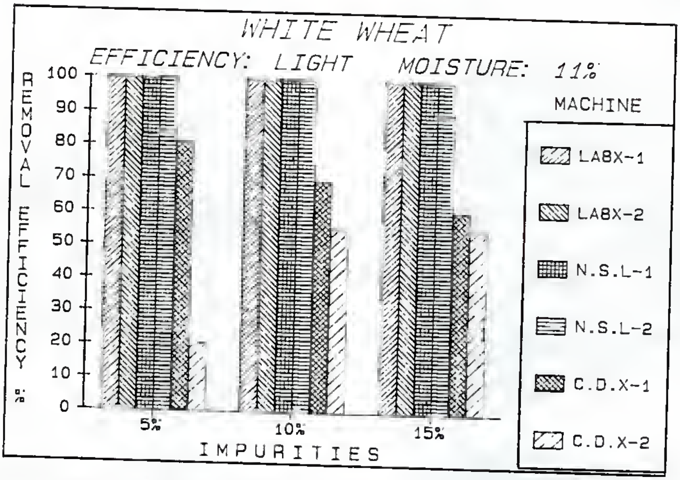

Figure A-7. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for White Wheat at 11% Moisture

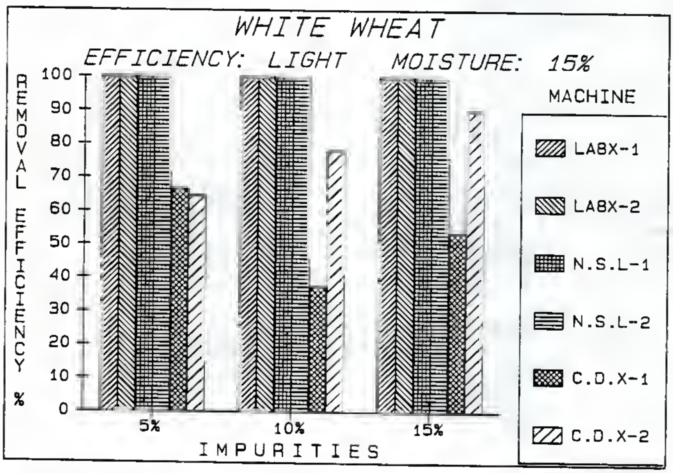

Figure A-8. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for White Wheat at 15% Moisture

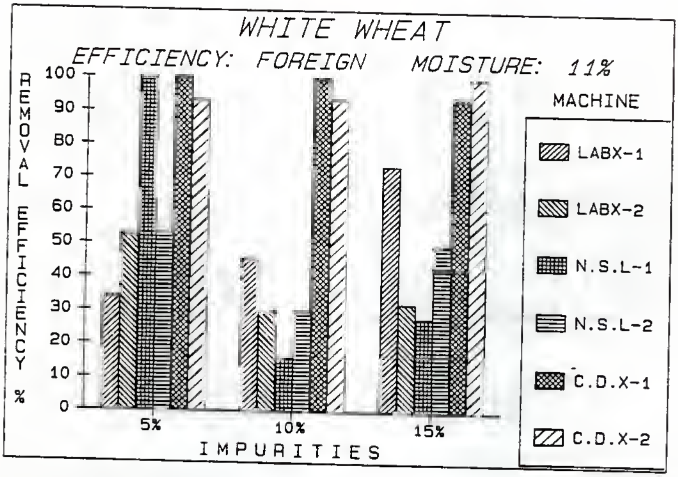

Figure A-9. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for White Wheat at 11% Moisture

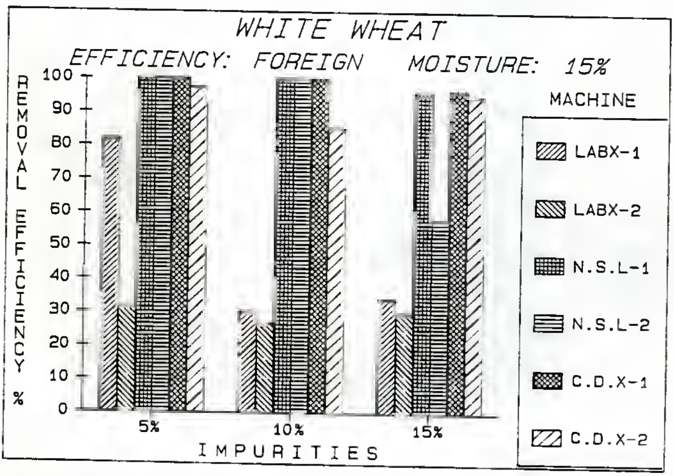

Figure A-10. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for White Wheat at 15% Moisture

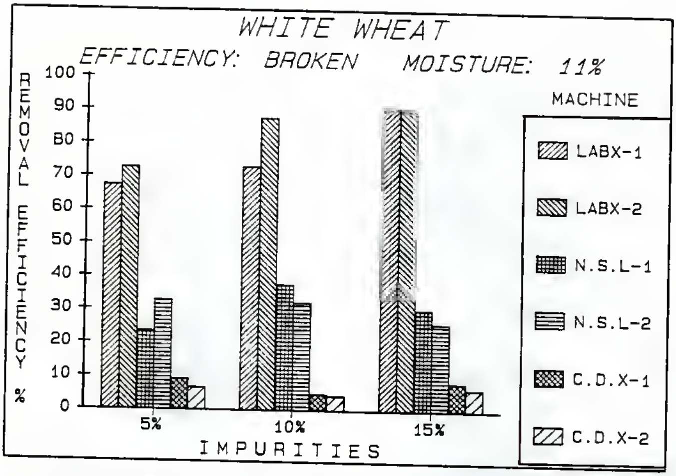

Figure A-11. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for White Wheat at 11% Moisture

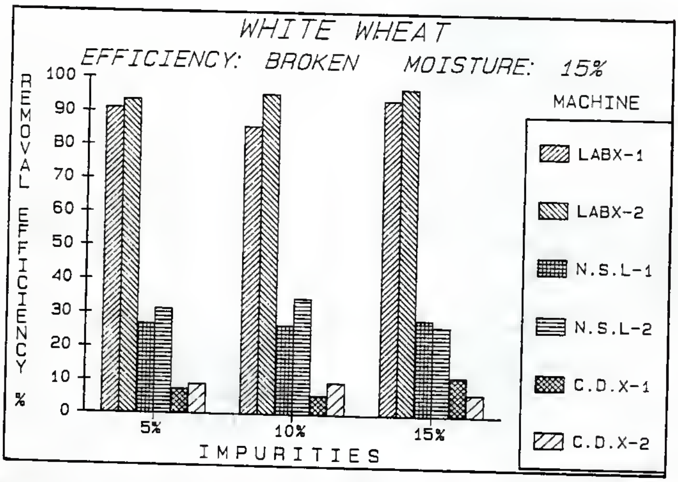

Figure A-12. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for White Wheat at 15% Moisture

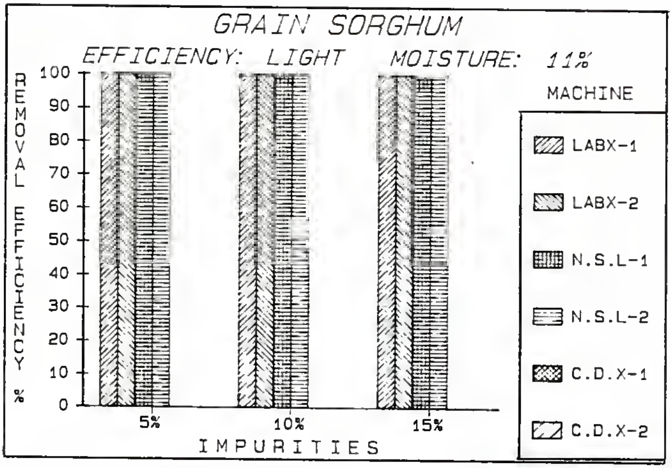

Figure A-13. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Sorghum at 11% Moisture

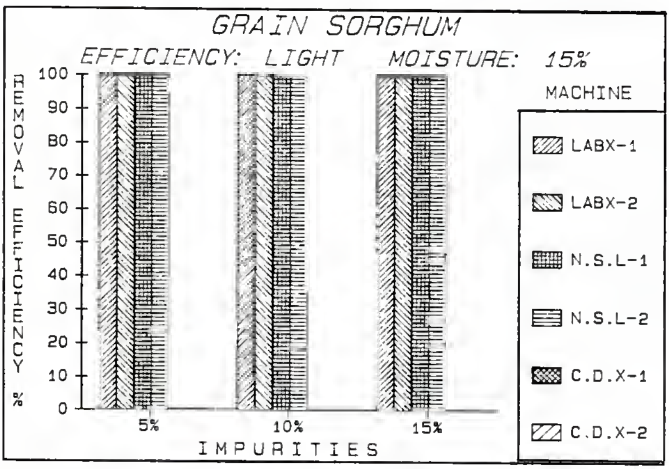

Figure A-14. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Sorghum at 15% Moisture

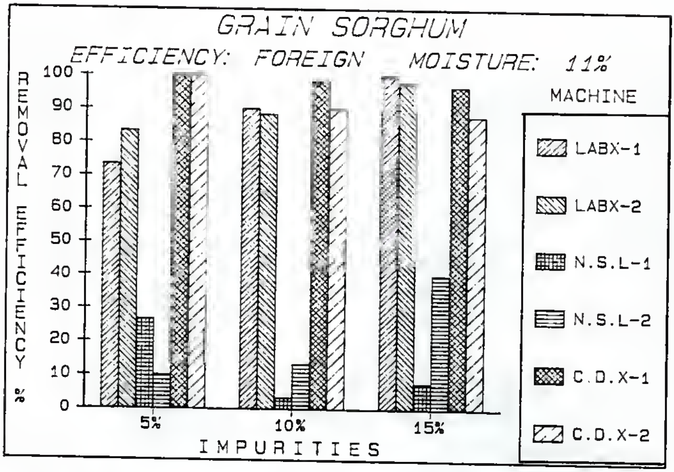

Figure A-15. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Sorghum at 11% Moisture

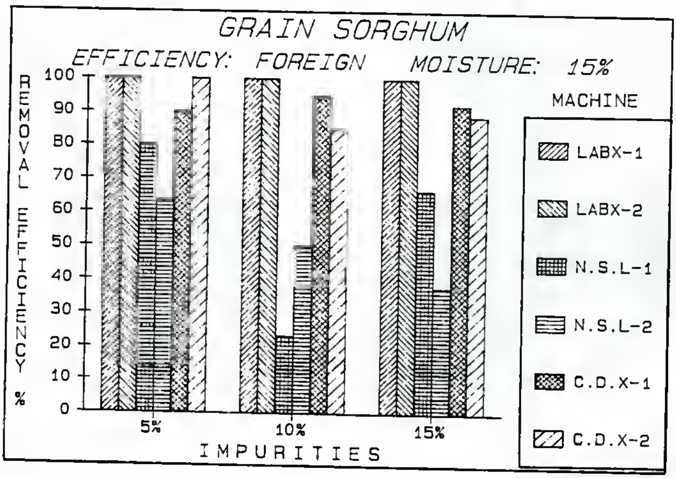

Figure A-16. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Sorghum at 15% Moisture

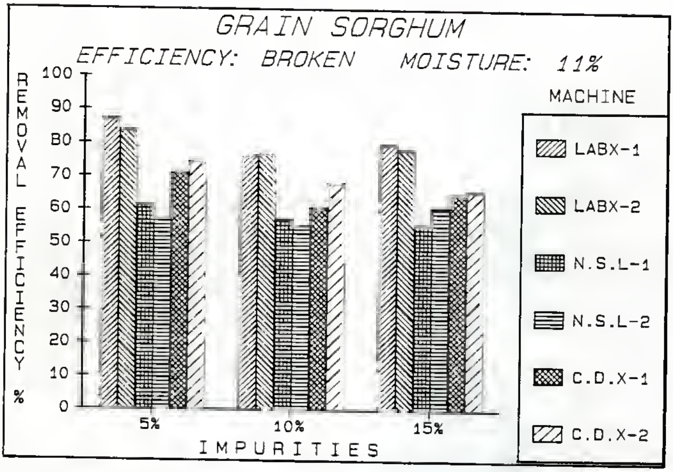

Figure A-17. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Sorghum at 11% Moisture

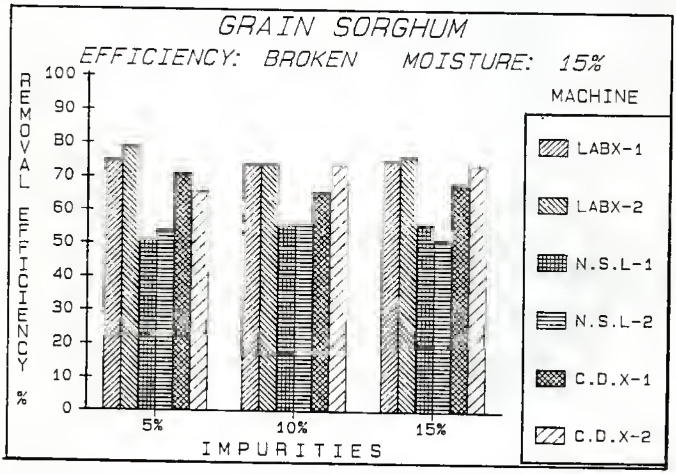

Figure A-18. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Sorghum at 15% Moisture

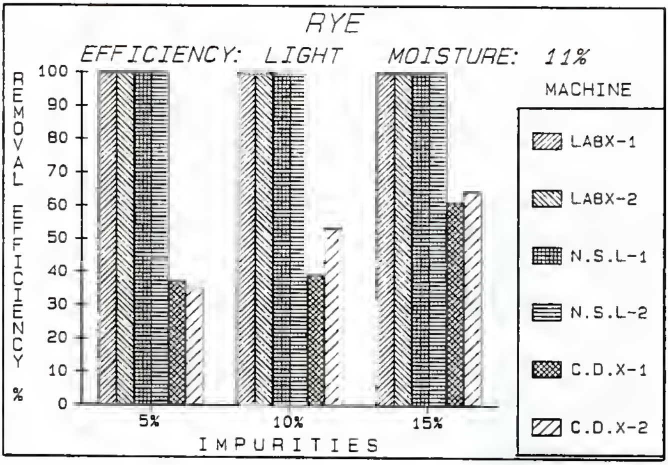

Figure A-19. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Rye at 11% Moisture

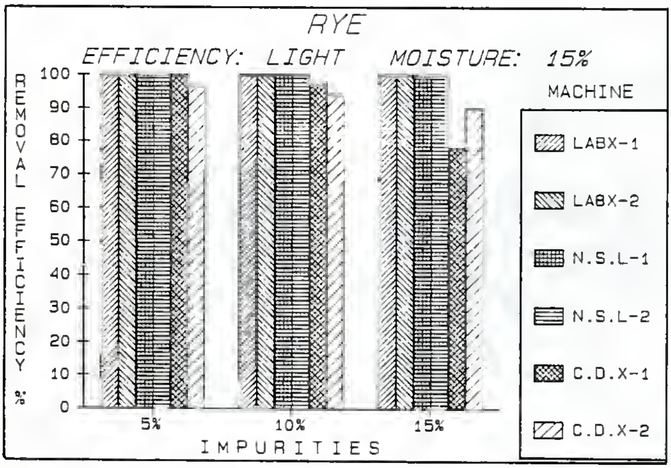

Figure A-20. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Rye at 15% Moisture

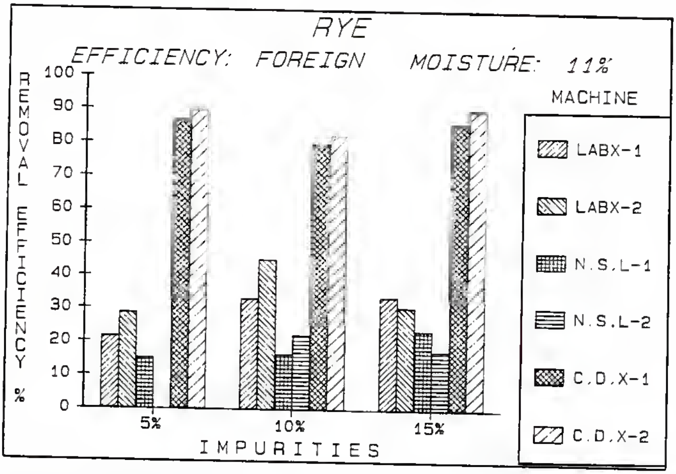

Figure A-21. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Rye at 11% Moisture

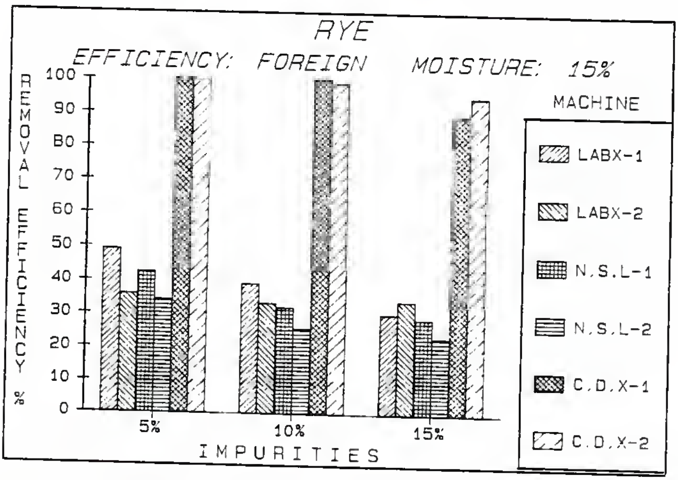

Figure A-22. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Rye at 15% Moisture

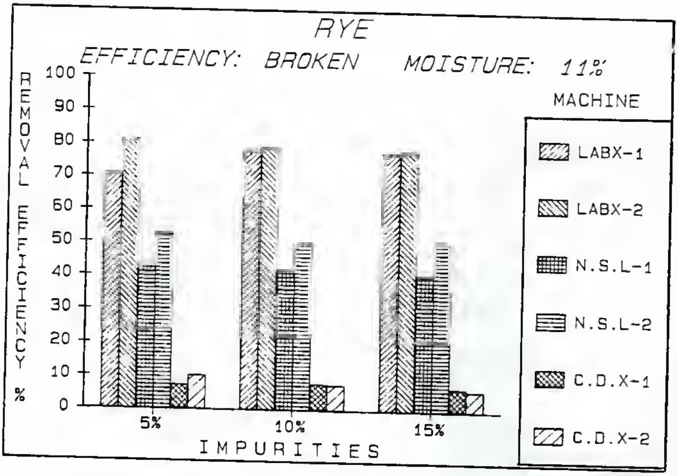

Figure A-23. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Rye at 11% Moisture

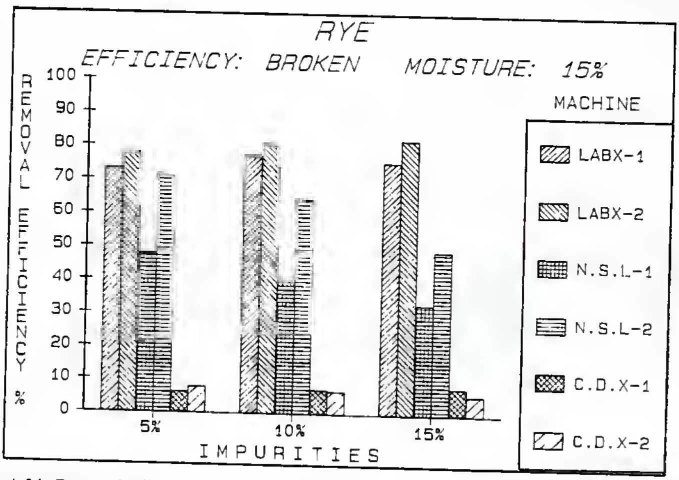

Figure A-24. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Rye at 15% Moisture

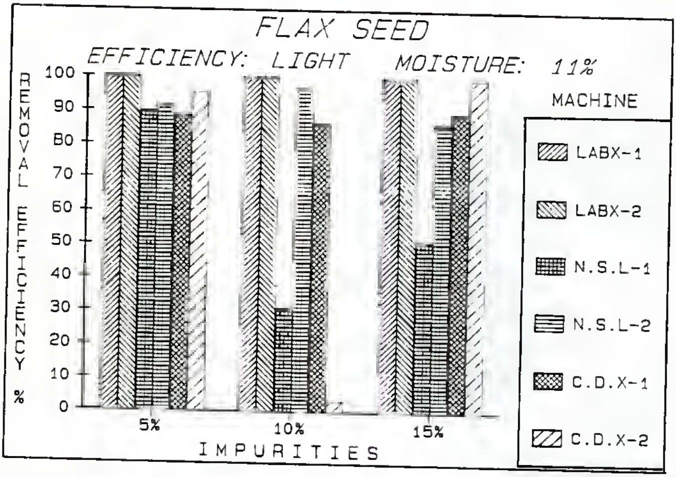

Figure A-25. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Flaxseed at 11% Moisture

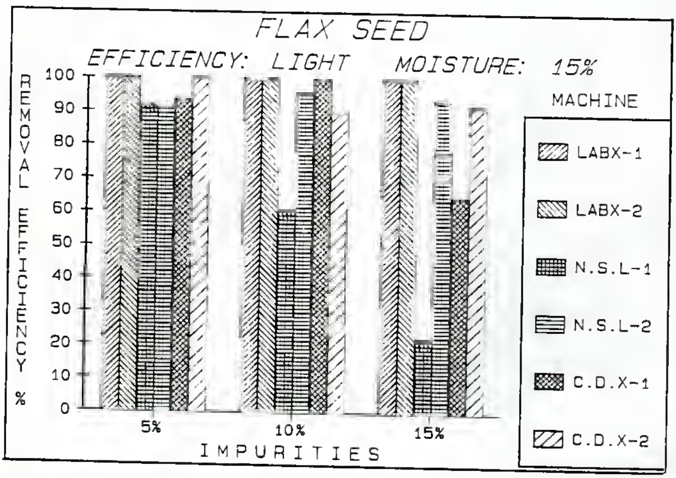

Figure A-26. Removal Efficiency of Light Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Flaxseed at 15% Moisture

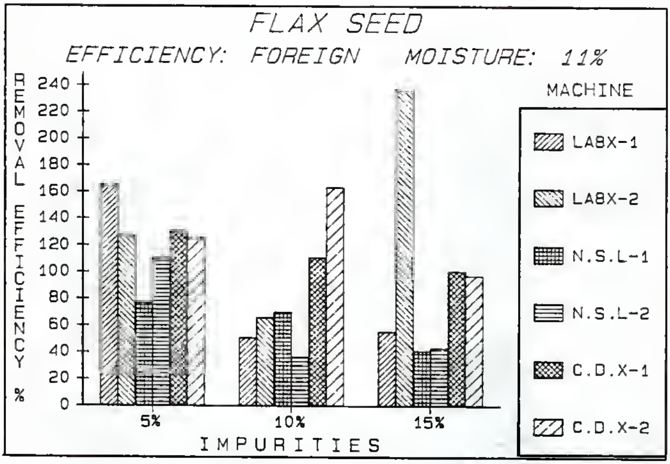

Figure A-27. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Flaxseed at 11% Moisture

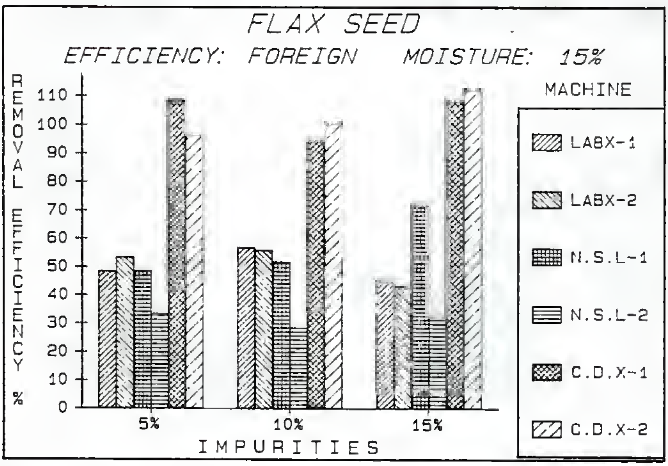

Figure A-28. Removal Efficiency of Foreign Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Flaxseed at 15% Moisture

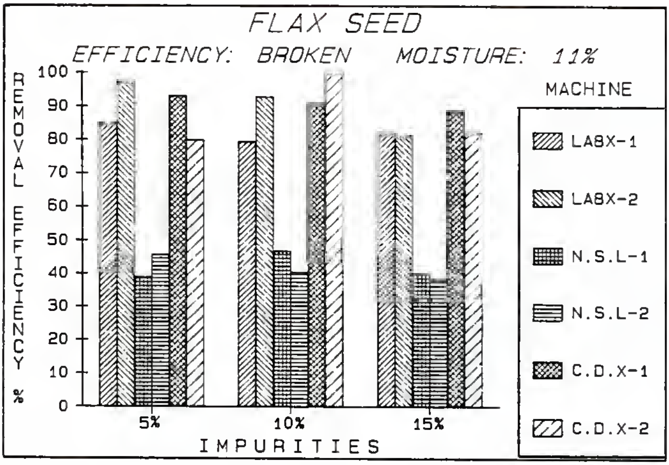

Figure A-29. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Flaxseed at 11% Moisture

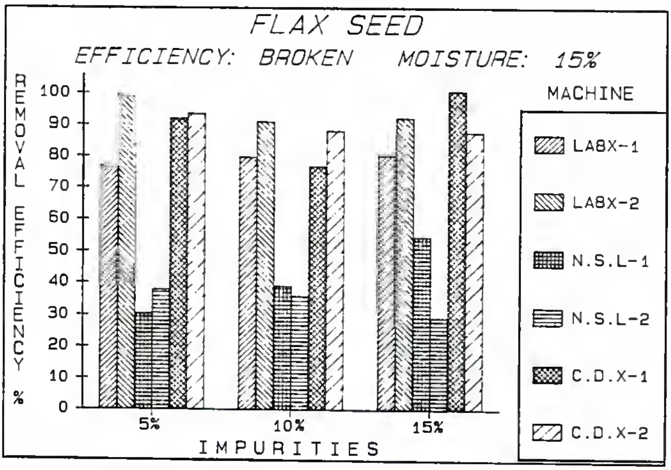

Figure A-30. Removal Efficiency of Broken Materials by Two Units Each of Labofix, N.S.L., and XT3 Models for Flaxseed at 15% Moisture

TABLE A-61. Statistical Analysis for the Moisture Content Effect on the Overall Removal Efficiency

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	NS	NS	NS	NS	S
White Wheat	S	S	S	NS	NS	S
Grain Sorghum	S	NS	S	S	NS	NS
Rye	NS	NS	NS	NS	S	S
Flaxseed	S	NS	NS	NS	NS	S

S = Statistically significant
NS = Statistically not significant

TABLE A-62. Statistical Analysis for the Impurity Level Effect on the Overall Removal Efficiency

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	S	NS	S	NS	S
White Wheat	S	S	S	NS	NS	NS
Grain Sorghum	S	NS	NS	NS	S	NS
Rye	NS	NS	NS	NS	NS	S
Flaxseed	NS	S	S	NS	S	S

S = Statistically significant
NS = Statistically not significant

TABLE A-63. Statistical Analysis for Units Effect on the Overall Removal Efficiency

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRS Wheat	S	S	NS
White Wheat	S	S	NS
Grain Sorghum	NS	NS	S
Rye	S	S	NS
Flaxseed	S	S	NS

S = Statistically significant
NS = Statistically not significant

TABLE A-64. Statistical Analysis for the Three Replicates on the Overall Removal Efficiency

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	NS	NS	NS	NS	NS
White Wheat	NS	NS	NS	NS	NS	NS
Grain Sorghum	NS	NS	NS	NS	NS	NS
Rye	NS	NS	NS	NS	NS	S
Flaxseed	NS	NS	NS	NS	NS	NS

S = Statistically significant
NS = Statistically not significant

TABLE A-65. Statistical Analysis for the Moisture Content Effect on the Removal Efficiency of Light Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS*	NS*	NS*	NS*	S	S
White Wheat	NS*	NS*	NS*	NS*	NS	S
Grain Sorghum	NS*	NS*	NS*	NS*	NS*	NS*
Rye	NS*	NS*	NS*	NS*	S	S
Flaxseed	NS*	NS*	NS	NS	NS	S

* Analysis based on adjusted data
S = Statistically significant
NS = Statistically not significant

TABLE A-66. Statistical Analysis for the Impurity Level Effect on the Removal Efficiency of Light Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS*	NS*	NS*	NS*	S	S
White Wheat	NS*	NS*	NS*	NS*	NS	S
Grain Sorghum	NS*	NS*	NS*	NS*	NS*	NS*
Rye	NS*	NS*	NS*	NS*	NS	NS
Flaxseed	NS*	NS*	S	NS	S	S

* Analysis based on adjusted data.
xxx No materials removed
S = Statistically significant
NS = Statistically not significant

TABLE A-67. Statistical Analysis for Units Effect on the Removal Efficiency of Light Materials

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRS Wheat	NS*	NS*	S
White Wheat	NS*	NS*	NS
Grain Sorghum	NS*	NS*	NS*
Rye	NS*	NS*	S
Flaxseed	NS*	S	S

* Analysis based on adjusted data
xxx No materials removed
S = Statistically significant
NS = Statistically not significant

TABLE A-68. Statistical Analysis for the Three Replicates on the Removal Efficiency of Light Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS*	NS*	NS*	NS*	NS	S
White Wheat	NS*	NS*	NS*	NS*	NS	NS
Grain Sorghum	NS*	NS*	NS*	NS*	NS*	NS*
Rye	NS*	NS*	NS*	NS*	NS	NS
Flaxseed	NS*	NS*	NS	NS	NS	NS

* Analysis based on adjusted data
xxx No materials removed
S = Statistically significant
NS = Statistically not significant

TABLE A-69. Statistical Analysis for the Moisture Content Effect on the Removal Efficiency of Foreign Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	NS	NS	S	NS	S
White Wheat	NS	S	S	S	NS	NS
Grain Sorghum	S	NS	NS	NS	NS	NS
Rye	S	NS	S	S	S	S
Flaxseed	NS	NS	NS	S	NS	S

xxx No materials removed
S = Statistically significant
NS = Statistically not significant

TABLE A-70. Statistical Analysis for the Impurity Level Effect on the Removal Efficiency of Foreign Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	NS	NS	NS	NS	NS
White Wheat	NS	S	S	NS	S	NS
Grain Sorghum	NS	NS	NS	NS	NS	NS
Rye	NS	NS	NS	NS	NS	S
Flaxseed	NS	NS	NS	NS	NS	S

xxx No materials removed.
S = Statistically significant
NS = Statistically not significant

TABLE A-71. Statistical Analysis for Units Effect on the Removal Efficiency of Foreign Materials

Crop \ Model	Labofix	N.S.L.	CD-XT 3
HRS Wheat	NS	NS	NS
White Wheat	NS	S	NS
Grain Sorghum	NS	NS	NS
Rye	NS	S	S
Flaxseed	S	NS	NS

S = Statistically significant
NS = Statistically not significant

TABLE A-72. Statistical Analysis for the Three Replicates on the Removal Efficiency of Foreign Materials

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	NS	NS	NS	NS	NS
White Wheat	NS	NS	NS	NS	NS	NS
Grain Sorghum	NS	NS	NS	NS	NS	NS
Rye	NS	NS	NS	NS	NS	NS
Flaxseed	NS	NS	NS	NS	NS	NS

S = Statistically significant
NS = Statistically not significant

TABLE A-73. Statistical Analysis for the Moisture Content Effect on the Removal Efficiency of Broken Kernels

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	S	NS	NS	S	S
White Wheat	S	S	NS	NS	NS	S
Grain Sorghum	S	NS	S	S	NS	NS
Rye	NS	NS	NS	NS	NS	S
Flaxseed	NS	S	NS	NS	NS	NS

S = Statistically significant
NS = Statistically not significant

TABLE A-74. Statistical Analysis for the Impurity Level Effect on the Removal Efficiency of Broken Kernels

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	S	NS	S	S	S
White Wheat	S	S	NS	NS	NS	NS
Grain Sorghum	S	NS	NS	NS	S	NS
Rye	NS	NS	S	NS	NS	S
Flaxseed	NS	S	S	NS	S	S

S = Statistically significant
NS = Statistically not significant

TABLE A-75. Statistical Analysis for Units Effect on the Removal Efficiency of Broken Kernels

Model / Crop	Labofix	N.S.L.	CD-XT 3
HRS Wheat	S	S	NS
White Wheat	S	NS	NS
Grain Sorghum	NS	NS	S
Rye	S	S	NS
Flaxseed	S	S	NS

S = Statistically significant
NS = Statistically not significant

TABLE A-76. Statistical Analysis for the Three Replicates on the Removal Efficiency of Broken Kernels

CROP	Labofix		N.S.L.		CD-XT 3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	NS	S	NS	NS	S	NS
White Wheat	NS	NS	NS	NS	NS	NS
Grain Sorghum	NS	NS	NS	NS	NS	NS
Rye	NS	NS	NS	NS	NS	S
Flaxseed	NS	NS	NS	NS	NS	NS

S = Statistically significant
NS = Statistically not significant

TABLE A-77. Summary Table on Removal Efficiencies for Hard Red Spring Wheat

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\overline{x} \pm S$	89.04 ± 5.63	100.0 ± 0.0	67.95 ± 7.85	90.48 ± 6.49
		Ranges	80.1 ~ 103.6	100.0	55.0 ~ 85.0	86.2 ~ 107.3
	Unit 2	$\overline{x} \pm S$	91.67 ± 3.11	100.0 ± 0.0	63.04 ± 10.11	93.91 ± 3.03
		Ranges	88.4 ~ 99.0	100.0	47.5 ~ 82.5	89.9 ~ 100.9
NSL	Unit 1	$\overline{x} \pm S$	32.56 ± 3.81	100.0 ± 0.0	47.71 ± 22.27	28.12 ± 3.00
		Ranges	24.6 ~ 37.20	100.0	2.5 ~ 81.7	23.2 ~ 32.8
	Unit 2	$\overline{x} \pm S$	51.32 ± 5.86	100.0 ± 0.0	52.02 ± 24.25	49.03 ± 7.3
		Ranges	37.7 ~ 58.8	100.0	0.0 ~ 97.5	33.4 ~ 62.3
CD	Unit 1	$\overline{x} \pm S$	16.13 ± 1.77	84.57 ± 18.82	92.11 ± 12.22	6.13 ± 2.72
		Ranges	13.0 ~ 19.2	52.5 ~ 100.0	52.5 ~ 107.5	3.0 ~ 12.13
	Unit 2	$\overline{x} \pm S$	15.63 ± 1.20	77.49 ± 15.87	95.63 ± 6.83	5.44 ± 2.45
		Ranges	13.9 ~ 17.4	45 ~ 100.0	80.0 ~ 107.5	3.2 ~ 10.2

TABLE A-78. Summary Table on Removal Efficiencies for White Wheat

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\overline{X} \pm S$	81.52 ± 10.42	100.0 ± 0.0	49.88 ± 29.6	83.56 ± 10.6
		Ranges	65.5 ~ 99.9	100.0	23.0 ~ 144.5	65.7 ~ 96.7
	Unit 2	$\overline{X} \pm S$	85.37 ± 6.99	100.0 ± 0.0	33.86 ± 9.71	89.4 ± 8.67
		Ranges	70.2 ~ 94.4	100.0	23.6 ~ 56.3	70.9 ~ 100.6
NSL	Unit 1	$\overline{X} \pm S$	43.32 ± 11.73	100.0 ± 0.0	161.2 ± 163.38	28.9 ± 5.28
		Ranges	29.2 ~ 73.3	100.0	12.4 ~ 547.3	20.7 ~ 38.4
	Unit 2	$\overline{X} \pm S$	37.87 ± 8.47	100.0 ± 0.0	87.13 ± 77.55	30.59 ± 6.34
		Ranges	24.2 ~ 54.2	100.0	11.9 ~ 236.8	21.4 ~ 46.0
CD	Unit 1	$\overline{X} \pm S$	17.61 ± 3.42	61.43 ± 19.62	101.82 ± 8.82	7.95 ± 3.96
		Ranges	12.9 ~ 27.3	1.8 ~ 93.5	90.5 ~ 130.3	1.1 ~ 17.1
	Unit 2	$\overline{X} \pm S$	16.27 ± 3.3	60.62 ± 24.55	94.07 ± 22.53	7.19 ± 2.27
		Ranges	6.6 ~ 19.5	5.5 ~ 95.3	20.0 ~ 133.5	1.2 ~ 10.2

TABLE A-79. Summary Table on Removal Efficiencies for Grain Sorghum

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\overline{x} \pm S$	79.55 ± 4.49	100.0 ± 0.0	99.91 ± 16.8	77.78 ± 5.13
		Ranges	78.8 – 88.6	100.0	70.0 ~ 120.0	72.0 ~ 88.5
	Unit 2	$\overline{x} \pm S$	79.83 ± 3.54	100.0 ± 0.0	105.01 ± 27.72	77.97 ± 3.94
		Ranges	72.9 ~ 87.2	100.0	70.0 ~ 200.0	70.3 ~ 86.5
NSL	Unit 1	$\overline{x} \pm S$	58.54 ± 2.84	100.0 ± 0.0	34.63 ± 43.52	56.36 ± 3.33
		Ranges	54.3 ~ 64.4	100.0	0.0 ~ 163.0	51.1 ~ 63.0
	Unit 2	$\overline{x} \pm S$	58.13 ± 3.14	100.0 ± 0.0	35.74 ± 50.31	55.88 ± 3.37
		Ranges	53.6 ~ 64.7	100.0	0.0 ~ 160.0	50.2 ~ 63.4
CD	Unit 1	$\overline{x} \pm S$	63.62 ± 3.86	0.0 ± 0.0	100.37 ± 27.94	66.99 ± 4.11
		Ranges	54.3 ~ 68.6	0.0	50.0 ~ 190.0	57.0 ~ 75.6
	Unit 2	$\overline{x} \pm S$	66.91 ± 4.85	0.0 ± 0.0	93.06 ± 14.16	70.34 ± 5.29
		Ranges	60.2 ~ 72.5	0.0	70.0 ~ 130.0	60.4 ~ 78.5

TABLE A-80. Summary Table on Removal Efficiencies for Rye

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\overline{X} \pm S$	72.96 ± 4.32	100. ± 0.0	34.44 ± 9.91	75.22 ± 4.61
		Ranges	65.4 ~ 83.5	100.0	20.5 ~ 47.5	67.8 ~ 86.3
	Unit 2	$\overline{X} \pm S$	76.89 ± 2.07	100.0 ± 0.0	34.58 ± 7.70	79.68 ± 2.23
		Ranges	72.4 ~ 80.5	100.0	20.8 ~ 47.5	75.8 ~ 82.7
NSL	Unit 1	$\overline{X} \pm S$	41.86 ± 4.69	100.0 ± 0.0	26.39 ± 12.51	41.11 ± 5.99
		Ranges	33.5 ~ 50.4	100.0	12.5 ~ 55.0	31.1 ~ 56.60
	Unit 2	$\overline{X} \pm S$	55.2 ± 11.99	100.0 ± 0.0	20.48 ± 12.04	56.32 ± 12.92
		Ranges	23.3 ~ 81.6	100.0	0.0 ~ 40.0	21.0 ~ 84.5
CD	Unit 1	$\overline{X} \pm S$	16.45 ± 1.61	68.78 ± 26.14	91.61 ± 11.51	7.21 ± 0.93
		Ranges	14.2 ~ 18.5	36.0 ~ 100.0	71.3 ~ 122.5	4.3 ~ 8.6
	Unit 2	$\overline{X} \pm S$	17.41 ± 2.67	72.29 ± 24.8	100.59 ± 22.91	7.37 ± 1.60
		Ranges	14.6 ~ 24.4	20.5 ~ 100.0	81.0 ~ 155	5.8 ~ 11.5

TABLE A-81. Summary Table on Removal Efficiencies for Flaxseed

Model			Removal Efficiency (%)			
			Overall	Light Materials	Foreign Materials	Broken Kernels
Lab	Unit 1	$\overline{X} \pm S$	87.08 ± 3.42	100.0 ± 0.0	70.23 ± 53.83	80.46 ± 3.47
		Ranges	82.4 ~ 95.6	100.0	25.0 ~ 265.0	75.7 ~ 91.3
	Unit 2	$\overline{X} \pm S$	95.23 ± 3.44	100.0 ± 0.0	96.94 ± 95.47	92.25 ± 6.55
		Ranges	88.9 ~ 100.0	100.0	31.7 ~ 423.3	77.0 ~ 106.0
NSL	Unit 1	$\overline{X} \pm S$	48.08 ± 7.95	57.63 ± 32.19	60.0 ± 18.42	41.56 ± 8.49
		Ranges	35.2 ~ 64.6	11.1 ~ 100.0	22.5 ~ 102.5	27.0 ~ 57.9
	Unit 2	$\overline{X} \pm S$	57. ± 5.44	92.48 ± 7.42	47.32 ± 36.16	37.84 ± 6.38
		Ranges	52.1 ~ 71.4	73.9 ~ 100.0	22.5 ~ 175.0	28.6 ~ 52.3
CD	Unit 1	$\overline{X} \pm S$	89.83 ± 2.8	86.98 ± 11.44	108.93 ± 17.09	90.28 ± 7.35
		Ranges	85.3 ~ 95.2	62.6 ~ 100.0	80.0 ~ 145.0	76.2 ~ 101.3
	Unit 2	$\overline{X} \pm S$	88.49 ± 5.6	80.14 ± 35.66	115.88 ± 25.38	91.7 ± 13.99
		Ranges	75.9 ~ 96.4	17 ~ 100.0	85.0 ~ 165.0	73.7 ~ 123.5

TABLE A-82. Coefficient of Variance for Overall Efficiency

Crop	Labofix		N.S.L.		CD-XT3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	6.32	3.39	11.70	11.41	10.97	7.68
White Wheat	12.78	8.19	27.72	22.37	19.42	20.28
Grain Sorghum	5.64	4.43	4.85	5.40	6.07	7.23
Rye	5.92	2.69	11.20	21.72	9.79	15.34
Flaxseed	3.93	3.61	16.53	9.40	3.12	6.33
Average	6.92	4.46	14.40	14.06	9.87	11.37
Total average	5.69		14.23		10.62	

TABLE A-83. Coefficient of Variance for Removal Efficiency of Light Material

Crop	Labofix		N.S.L.		CD-XT3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	0.0*	0.0*	0.0*	0.0*	22.25	20.48
White Wheat	0.0*	0.0*	0.0*	0.0*	31.94	40.5
Grain Sorghum	0.0*	0.0*	0.0*	0.0*	-	-
Rye	0.0*	0.0*	0.0*	0.0*	38.00	34.31
Flaxseed	0.0*	0.0*	55.86	8.02	13.15	44.5
Average	-	-	-	-	26.34	34.95
Total average	-		31.94		30.64	

*Correspond to modified efficiencies.

TABLE A-84. Coefficient of Variance for Removal Efficiency of Foreign Material

Crop	Labofix		N.S.L.		CD-XT3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	11.55	16.04	46.68	46.62	13.27	7.14
White Wheat	59.34	28.68	101.35	89.00	8.66	23.95
Grain Sorghum	16.82	26.40	125.67	140.77	27.84	15.22
Rye	28.77	22.27	47.40	58.78	12.56	22.78
Flaxseed	76.65	98.48	30.70	76.42	15.69	21.90
Average	38.63	38.37	70.36	82.32	15.60	18.20
Total average	38.50		76.34		16.90	

TABLE A-85. Coefficient of Variance for Removal Efficiency of Broken Material

Crop	Labofix		N.S.L.		CD-XT3	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
HRS Wheat	7.17	3.23	10.67	14.89	44.37	45.04
White Wheat	12.69	9.70	18.27	20.73	49.81	31.57
Grain Sorghum	6.60	5.05	5.91	6.03	6.14	7.52
Rye	6.13	2.80	14.57	22.94	12.90	21.71
Flaxseed	4.31	7.10	20.43	16.86	8.14	15.26
Average	7.38	5.58	13.97	16.29	24.27	24.22
Total average	6.48		15.13		24.25	

TABLE A-86. Broken/Sound Kernel Fractions Separated by Mechanical Shaker (g/g)

Grain Type: Hard Red Spring Wheat Machine: CD-XT 3 - 1

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	4.8 / 249.33	10.67 / 233.20	14.83 / 228.47
15	5.3 / 242.33	10.70 / 234.43	16.03 / 227.40

Grain Type: Hard Red Spring Wheat Machine: CD-XT 3 - 2

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	5.7 / 241.13	10.43 / 233.43	14.9 / 226.37
15	5.43 / 241.27	10.7 / 233.37	16.03 / 227.4

TABLE A-87. Broken/Sound Kernel Fractions Separated by Mechanical Shaker (g/g)

Grain Type: White Wheat Machine: CD-XT 3 - 1

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	3.34 / 240.97	6.91 / 238.17	11.70 / 231.64
15	4.57 / 242.80	7.74 / 235.54	10.88 / 234.59

Grain Type: White Wheat Machine: CD-XT 3 - 2

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	3.83 / 243.17	8.41 / 237.40	13.41 / 229.29
15	4.54 / 243.14	8.90 / 250.04	12.62 / 231.34

TABLE A-88. Broken/Sound Kernel Fractions Separated by Mechanical Shaker (g/g)

Grain Type: Rye Machine: CD-XT 3-1

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	9.14/235.83	17.96/226.07	27.16/213.13
15	9.0/236.73	18.50/222.63	27.90/210.80

Grain Type: Rye Machine: CD-XT 3-2

Moisture Content % (W.B.)	Impurity level (%)		
	5	10	15
11	8.69/235.63	17.46/226.00	27.57/212.43
15	8.8/236.13	17.96/225.03	27.73/212.60

TABLE A-89. Data for Hard Red Spring Wheat from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Broken kernels, foreign materials & other grains (%)	Damaged kernels (%)	U.S. No.
SP-M11-I5	11.8	57.9	0.8	0.2	2.4		0.4	3 hard red winter wheat
SP-M11-I10	11.2	58.1	1.3	0.1	4.7		0.3	3 hard red winter wheat
SP-M11-I15	10.9	58.0	1.9	0.1	7.1		0.4	3 hard red winter wheat
SP-M15-I5	14.9	57.7	0.7	0.0	2.3		0.6	3 hard red winter wheat
SP-M15-I10	15.2	58.7	1.1	0.2	4.5		0.3	3 hard red winter wheat
SP-M15-I15	15.6	57.4	1.9	0.2	7.0		0.4	3 hard red winter wheat

TABLE A-90. Data for Soft White Wheat from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Broken kernels, foreign materials & other grains (%)	Damaged kernels (%)	U.S. No.
HI-M11-I5	11.1	59.4	0.7	0.2	1.6		0.4	2 soft white wheat
HI-M11-I10	10.5	59.9	1.3	0.1	3.2		0.4	2 soft white wheat
HI-M11-I15	11.0	59.8	2.0	0.1	5.5		0.3	3 soft white wheat
HI-M15-I5	14.0	56.9	2.1	0.1	4.1		0.0	3 soft white wheat
HI-M15-I10	14.6	57.0	1.7	0.1	3.2		0.1	3 soft white wheat
HI-M15-I15	14.4	56.3	2.3	0.1	5.5		0.0	3 soft white wheat

TABLE A-91. Data for Grain Sorghum from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Broken kernels, foreign materials & other grains (%)	Damaged kernels (%)	U.S. No.
GR-M11-I5	12.6	59.5		0.3	2.9		0.8	1 yellow sorghum
GR-M11-I10	11.3	59.5	2.0	0.7	4.1		1.7	2 yellow sorghum
GR-M11-I15	12.0	60.5	3.0	0.8	5.6		2.1	2 yellow sorghum
GR-M15-I5	14.9	60.0	1.0	0.3	2.1		1.9	1 yellow sorghum
GR-M15-I10	15.6	59.5	2.0	0.5	3.4		0.6	1 yellow sorghum
GR-M15-I15	14.9	59.0	3.0	0.9	6.2		2.6	2 yellow sorghum

TABLE A-92. Data for Rye from the Kansas State Grain Inspection Service

Identification of sample	Moisture Content (%)	Test weight per bushel (lbs)	Dockage (%)	Foreign material (%)	Shrunken and/or broken kernels (%)	Broken kernels, foreign materials & other grains (%)	Damaged kernels (%)	U.S. No.
RY-M11-I5	11.6	55.0	-	0.1	4.1 (thin rye)		3.4	2 plump rye
RY-M11-I10	11.3	55.0	2.0	0.3	11.9 (thin rye)		0.3	2 rye
RY-M11-I15	11.3	55.0	-	0.3	7.9 (thin rye)		0.3	2 rye
RY-M15-I5	15.3	52.0	-	0.2	3.8 (thin rye)		0.2	3 plump rye
RY-M15-I10	14.7	54.5	1.0	0.3	7.5 (thin rye)		1.0	2 rye
RY-M15-I10	14.1	55.1	2.0	0.1	11.8 (thin rye)		0.7	2 rye

TABLE A-93. Regression Analysis for the Moisture Content and Impurity Level Effect on the Overall Removal Efficiency

Crop	Labofix		N.S.L.		XT3	
	MC	IM	MC	IM	MC	IM
HRS Wheat	NS	NS	NS	NS	S-	S-
White Wheat	S+	S+	S+	S-	NS	NS
Grain Sorghum	S-	S-	S-	NS	NS	NS
Rye	NS	NS	NS	NS	S+	S-
Flaxseed	NS	NS	NS	S-	NS	NS

S: Slope statistically significant.
NS: Slope not statistically significant.
S+: Positive Slope
S-: Negative Slope
α: 0.05
MC: Moisture Content
IM: Impurity Level

TABLE A-94. Regression Analysis for the Moisture Content and Impurity Level Effect on the Removal Efficiency of Light Material

Crop	Labofix		N.S.L.		XT3	
	MC	IM	MC	IM	MC	IM
HRS Wheat	NS	NS	NS	NS	S+	S+
White Wheat	NS	NS	NS	NS	NS	NS
Grain Sorghum	NS	NS	NS	NS	---	---
Rye	NS	NS	NS	NS	S+	NS
Flaxseed	NS	NS	NS	S-	NS	NS

S: Slope statistically significant.
NS: Slope not statistically significant.
S+: Positive Slope
S-: Negative Slope
α: 0.05
MC: Moisture Content
IM: Impurity Level

TABLE A-95. Regression Analysis for the Moisture Content and Impurity Level Effect on the Removal Efficiency of Foreign Material

Crop	Labofix		N.S.L.		XT3	
	MC	IM	MC	IM	MC	IM
HRS Wheat	NS	S-	S+	S+	S+	NS
White Wheat	NS	NS	S+	S-	NS	NS
Grain Sorghum	S+	NS	S+	NS	NS	NS
Rye	NS	NS	S+	NS	S+	S-
Flaxseed	S-	NS	NS	NS	S-	NS

S: Slope statistically significant.
NS: Slope not statistically significant.
S+: Positive Slope
S-: Negative Slope
α: 0.05
MC: Moisture Content
IM: Impurity Level

TABLE A-96. Regression Analysis for the Moisture Content and Impurity Level Effect on the Removal Efficiency of Broken Kernels

Crop	Labofix		N.S.L.		XT3	
	MC	IM	MC	IM	MC	IM
HRS Wheat	NS	NS	NS	NS	S-	S-
White Wheat	S+	S+	NS	NS	NS	NS
Grain Sorghum	S-	S-	S-	NS	NS	NS
Rye	NS	NS	NS	S-	NS	S-
Flaxseed	NS	NS	NS	NS	NS	NS

S: Slope statistically significant.
NS: Slope not statistically significant.
S+: Positive Slope
S-: Negative Slope
α: 0.05
MC: Moisture Content
IM: Impurity Level

TABLE A-97. XT3 Test Results for Light and Broken Materials Removed from HRS Wheat (grams)

Materials Removed	Moisture content	Impurity Level 5% Unit 1	5% Unit 2	10% Unit 1	10% Unit 2	15% Unit 1	15% Unit 2
Light	11%	0.8	1.0	3.9	3.1	5.3	5.1
		1.0	1.0	3.1	2.6	5.1	5.0
		1.0	0.9	3.5	2.5	5.3	5.2
	15%	2.4	1.8	3.8	4.0	6.1	5.3
		2.0	1.7	3.5	3.5	5.6	5.0
		2.1	1.7	3.3	3.5	6.0	5.0
Broken	11%	4.4	4.0	6.6	6.1	5.9	6.6
		4.7	4.1	7.6	7.2	6.4	7.3
		5.4	4.5	6.8	7.3	6.7	7.2
	15%	1.4	1.7	2.6	3.2	5.1	4.8
		2.4	1.6	3.5	3.2	5.3	3.3
		1.7	1.5	3.5	3.2	5.5	4.2

TABLE A-98. N.S.L. Test Results for Light and Broken Materials Removed from HRS Wheat (grams)

Materials Removed	Moisture content	Impurity Level 5% Unit 1	5% Unit 2	10% Unit 1	10% Unit 2	15% Unit 1	15% Unit 2
Light	11%	8.0	24.8	26.7	39.2	35.6	24.8
		11.0	27.5	19.7	38.2	28.0	61.8
		7.9	28.7	24.0	44.8	29.0	70.4
	15%	9.6	24.1	19.0	46.8	27.7	56.1
		8.8	25.5	24.4	48.6	24.9	47.5
		9.9	24.1	23.8	37.6	30.8	
Broken	11%	4.2	0.9	6.2	5.6	10.6	25.3
		3.9	0.7	9.0	5.0	12.0	6.8
		4.4	0.7	8.0	2.4	11.7	7.4
	15%	4.6	1.1	9.1	1.5	14.5	7.7
		4.3	1.0	8.3	1.6	12.9	14.4
		5.0	0.9	7.9	14.1	13.1	9.9

TABLE A-99. Labofix Test Results for Light and Broken Materials Removed from HRS Wheat (grams)

Materials Removed	Moisture content	Impurity Level					
		5%		10%		15%	
		Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
Light	11%	8.3 7.8 7.1	9.1 9.0 8.9	16.2 18.2 22.2	15.2 14.9 13.1	30.3 24.1 28.6	21.5 21.6 23.8
	15%	13.8 8.9 9.4	8.0 7.9 7.4	13.8 14.7 14.1	18.6 14.0 15.0	22.1 22.2 21.3	23.9 21.3 24.1
Broken	11%	31.4 34.1 33.2	32.7 34.7 33.7	65.7 68.3 64.6	70.7 71.6 72.8	101.2 104.9 103.4	106.4 109.1 106.3
	15%	35.4 35.2 34.2	38.3 38.5 38.8	59.5 64.5 61.9	70.3 70.9 68.1	100.4 98.6 98.5	104.3 105.9 102.9

TABLE A-100. XT3 Test Results for Light and Broken Materials Removed from White Wheat (grams)

Materials Removed	Moisture content	Impurity Level					
		5%		10%		15%	
		Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
Light	11%	1.9 1.3 1.7	0.6 0.5 0.1	3.3 2.5 2.5	2.7 1.8 2.0	3.5 4.3 3.1	2.5 3.3 4.2
	15%	1.6 1.1 1.3	1.5 1.3 1.1	0.1 2.0 2.4	3.1 3.5 2.7	3.0 3.0 3.7	4.9 5.6 5.7
Broken	11%	7.5 4.0 4.0	3.8 2.5 2.4	3.7 4.8 4.3	4.8 5.7 1.1	9.4 13.4 10.5	8.9 9.7 7.4
	15%	2.8 3.4 3.7	4.4 3.5 3.9	9.1 4.0 2.3	8.9 8.15 8.7	13.9 17.6 15.8	6.7 10.8 9.43

TABLE A-101. N.S.L. Test Results for Light and Broken Materials Removed from White Wheat (grams)

Materials Removed	Moisture content	Impurity Level 5% Unit 1	5% Unit 2	10% Unit 1	10% Unit 2	15% Unit 1	15% Unit 2
Light	11%	10.1	15.4	32.8	43.4	29.3	30.5
		8.1	10.46	35.4	13.3	23.3	14.2
		10.6	15.85	33.8	10.9	34.6	15.1
	15%	11.9	10.8	15.2	27.7	37.9	22.1
		8.7	11.9	20.3	20.9	29.1	29.0
		12.3	6.3	24.3	16.1	34.7	24.5
Broken	11%	3.2	1.6	3.7	1.2	12.5	13.6
		2.9	3.9	2.4	9.5	26.8	25.1
		1.9	1.8	2.5	18.7	11.6	22.9
	15%	2.9	5.6	7.4	4.9	8.4	20.8
		2.9	4.6	9.6	21.4	12.3	12.6
		2.5	8.0	5.6	12.5	9.2	14.6

TABLE A-102. Labofix Test Results for Light and Broken Materials Removed from White Wheat (grams)

Materials Removed	Moisture content	Impurity Level 5% Unit 1	5% Unit 2	10% Unit 1	10% Unit 2	15% Unit 1	15% Unit 2
Light	11%	7.4	8.6	12.3	15.3	21.7	19.7
		8.7	7.9	14.0	13.6	26.4	18.6
		8.3	9.0	15.5	12.7	19.5	18.1
	15%	6.7	7.3	12.6	20.3	34.4	26.7
		6.5	7.6	16.4	16.4	20.8	26.5
		7.8	7.9	12.0	19.0	26.1	23.1
Broken	11%	23.4	25.4	56.1	67.7	104.3	103.8
		22.8	25.3	50.3	67.7	98.8	108.1
		23.9	25.5	56.2	65.8	105.9	107.3
	15%	37.4	35.0	63.9	72.2	99.2	106.1
		34.6	35.6	65.8	68.5	106.7	110.4
		33.0	35.9	67.4	67.4	102.3	110.1

TABLE A-103. XT3 Test Results for Light and Broken Materials Removed from Grain Sorghum (grams)

Materials Removed	Moisture content	Impurity Level 5%		10%		15%	
		Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
Light	11%	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0
	15%	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0
Broken	11%	32.0	33.8	58.3	67.7	88.9	90.3
		34.1	33.0	52.4	58.6	90.4	91.2
		32.0	36.1	57.0	62.1	90.0	91.2
	15%	31.7	33.9	59.5	68.2	94.2	105.8
		33.8	29.0	62.1	67.7	93.3	103.2
		32.3	27.8	59.8	68.2	95.6	104.8

TABLE A-104. N.S.L. Test Results for Light and Broken Materials Removed from Grain Sorghum (grams)

Materials Removed	Moisture content	Impurity Level 5%		10%		15%	
		Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
Light	11%	20.5	18.8	28.4	39.7	44.6	63.1
		20.2	20.6	26.2	39.1	49.7	60.7
		19.7	19.8	27.8	38.8	57.0	64.9
	15%	15.4	18.7	35.0	41.1	50.1	52.0
		14.5	19.0	35.3	39.6	55.3	53.7
		15.1	17.5	36.0	38.0	53.6	51.3
Broken	11%	11.5	9.7	30.4	17.8	40.7	27.3
		10.9	9.8	31.4	17.7	31.4	35.8
		10.7	9.8	32.0	17.7	34.5	27.3
	15%	11.1	9.7	22.1	17.8	34.6	28.4
		12.5	8.8	22.9	18.2	32.8	24.6
		11.5	9.4	22.2	19.1	32.2	29.3

TABLE A-105. Labofix Test Results for Light and Broken Materials Removed from Grain Sorghum (grams)

Materials Removed	Moisture content	Impurity Level 5%		10%		15%	
		Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
Light	11%	19.2 17.8 18.8	19.0 18.9 18.5	35.1 37.3 37.9	39.4 40.2 40.7	53.4 56.2 59.0	55.5 53.5 55.5
	15%	16.9 16.9 21.4	19.0 19.2 19.3	33.1 34.4 34.1	35.7 34.7 36.5	51.6 49.4 50.0	53.1 55.5 53.4
Broken	11%	22.8 21.9 24.0	23.5 24.8 24.4	40.0 40.2 38.4	37.9 36.2 36.8	64.5 61.1 63.4	65.8 58.8 61.5
	15%	19.5 19.2 18.2	20.0 20.1 20.2	42.9 37.0 40.0	38.7 37.7 40.1	62.9 60.3 63.0	54.7 62.0 63.4

TABLE A-106. XT3 Test Results for Light and Broken Materials Removed from Flax Seed (grams)

Materials Removed	Moisture content	Impurity Level 5%		10%		15%	
		Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
Light	11%	15.6 15.8 16.3	17.2 17.5 17.0	30.7 31.3 31.1	1.7 1.1 0.6	46.6 49.2 49.1	57.9 58.2 57.1
	15%	16.3 16.6 17.5	20.0 19.3 19.8	32.8 32.6 31.9	36.8 37.0 36.7	34.7 36.0 33.8	51.4 49.5 47.9
Broken	11%	21.8 21.5 21.2	20.8 19.9 20.2	54.2 53.7 55.3	74.1 71.6 68.7	79.6 79.3 80.4	69.2 69.4 71.6
	15%	27.5 27.7 27.5	25.9 26.8 26.3	50.8 53.8 54.0	44.9 45.2 45.6	91.0 91.2 89.6	78.7 78.8 79.3

TABLE A-107. N.S.L. Test Results for Light and Broken Materials Removed from Flax Seed (grams)

Materials Removed	Moisture content	Impurity Level 5% Unit 1	5% Unit 2	10% Unit 1	10% Unit 2	15% Unit 1	15% Unit 2
Light	11%	14.8	18.3	21.7	46.3	49.6	46.0
		20.3	13.3	7.6	40.6	19.9	44.5
		15.6	23.7	4.0	32.4	13.2	49.3
	15%	16.6	15.6	29.0	31.2	12.8	51.2
		16.7	16.8	22.3	40.8	12.2	51.8
		16.2	16.9	13.9	39.3	11.0	48.9
Broken	11%	12.1	12.8	24.9	19.3	30.3	32.6
		10.3	12.3	30.1	20.0	38.2	36.0
		10.3	10.0	29.3	18.6	39.2	34.3
	15%	8.1	11.2	21.1	20.7	46.0	25.7
		9.5	11.7	22.7	17.7	48.3	25.8
		9.7	11.1	26.2	18.0	52.1	27.4

TABLE A-108. Labofix Test Results for Light and Broken Materials Removed from Flax Seed (grams)

Materials Removed	Moisture content	Impurity Level 5% Unit 1	5% Unit 2	10% Unit 1	10% Unit 2	15% Unit 1	15% Unit 2
Light	11%	18.5	23.2	42.7	53.9	73.8	78.1
		19.0	22.5	44.3	54.8	74.8	72.8
		20.8	23.0	41.0	54.2	72.8	75.8
	15%	21.6	24.5	46.4	52.4	75.4	85.6
		22.0	25.7	46.8	54.2	74.4	87.6
		21.8	26.1	46.0	54.2	75.9	86.5
Broken	11%	24.0	23.0	40.7	37.6	53.4	51.9
		23.5	24.4	41.3	36.9	53.7	50.5
		24.6	25.3	40.8	37.6	54.8	52.5
	15%	19.9	21.5	36.7	37.5	50.8	49.5
		18.7	21.8	37.7	36.4	51.4	51.5
		19.0	23.7	37.9	37.0	50.6	50.1

TABLE A-109. XT3 Test Results for Light and Broken Materials Removed from Rye (grams)

Materials Removed	Moisture content	Impurity Level 5% Unit 1	5% Unit 2	10% Unit 1	10% Unit 2	15% Unit 1	15% Unit 2
Light	11%	0.8	0.6	1.6	3.0	3.8	3.5
		.7	0.7	1.6	1.8	3.6	4.0
		0.7	0.7	1.5	1.6	3.6	4.1
	15%	2.0	2.3	4.5	3.7	5.1	5.5
		2.2	2.0	4.4	3.9	4.2	5.3
		2.2	1.8	3.7	3.7	4.7	5.4
Broken	11%	3.1	5.1	6.9	6.8	8.2	8.4
		3.1	4.5	6.7	6.9	9.4	7.6
		3.3	3.7	7.0	6.2	9.4	8.0
	15%	1.9	3.7	6.3	6.0	10.3	7.8
		3.0	3.1	6.2	6.1	11.3	7.7
		2.9	3.1	5.5	5.8	10.4	7.9

TABLE A-110. N.S.L. Test Results for Light and Broken Materials Removed from Rye (grams)

Materials Removed	Moisture content	Impurity Level 5% Unit 1	5% Unit 2	10% Unit 1	10% Unit 2	15% Unit 1	15% Unit 2
Light	11%	11.7	14.5	23.1	33.3	27.5	58.4
		12.6	19.3	23.9	37.1	26.6	53.5
		11.2	20.1	22.2	31.4	33.2	49.1
	15%	10.7	10.2	12.4	53.8	13.1	16.4
		12.0	23.4	26.3	57.6	12.6	62.2
		5.4	25.4	23.9	45.1	19.1	58.6
Broken	11%	8.8	7.7	17.8	14.2	29.8	18.5
		10.2	6.9	17.6	12.7	31.2	19.0
		8.5	6.7	17.5	15.7	29.8	20.9
	15%	12.3	29.0	21.5	7.9	36.4	17.3
		11.1	6.2	16.3	8.1	34.3	29.7
		13.5	5.7	18.7	11.3	33.4	28.1

TABLE A-111. Labofix Test Results for Light and Broken Materials Removed from Rye (grams)

Materials Removed	Moisture content	Impurity Level 5%		10%		15%	
		Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
Light	11%	3.55 3.85 2.8	4.2 5.3 4.8	9.4 7.6 7.7	11.0 13.6 14.3	15.0 17.0 18.0	24.2 24.4 26.1
	15%	5.4 5.5 4.7	6.9 6.7 7.3	9.4 8.7 9.8	14.4 16.0 16.0	10.8 14.1 14.0	22.5 24.9 25.1
Broken	11%	30.3 29.5 29.0	33.9 31.4 33.1	60.7 64.2 68.2	61.2 59.1 60.9	90.5 90.1 94.4	89.4 83.0 80.0
	15%	27.6 30.0 29.0	28.9 29.9 28.8	70.5 57.0 60.1	60.7 57.7 60.1	90.2 90.9 96.4	92.7 89.0 89.1

EVALUATING THE PERFORMANCE OF LABORATORY MODEL GRAIN CLEANING AND SEPARATING EQUIPMENT FOR GRADING DIFFERENT CLASSES OF GRAIN

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B. S., Universidad de Costa Rica, 1983

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1989

ABSTRACT

Three different laboratory grain cleaners were tested in order to determine their feasibility as grain graders. These machines were: 1) Dockage Tester, model XT3 , made by Carter Day (USA), 2) Mini Cleaner and Grader, Labofix, made by MCK Maschinnenbau (West Germany), and 3) Laboratory Separator Cleaner, N.S.L., made by Tripette and Renaud (France).

The objectives of this research were: 1) to analyze the performance of the three types of grain cleaning and separating equipment, and 2) to suggest modifications of the grain cleaning and separating equipment to improve separation and use for grading grain.

Data on the performance of all three machines have been collected and analyzed from tests with five different crops: hard red spring wheat, white wheat, grain sorghum, rye, and flaxseed. Two units of each laboratory cleaner and tested. In testing the equipment, two levels of moisture content (11 and 15 percent) and three levels of impurities (5, 10, and 15 percent) in the sample were used. For each individual combination of moisture content and impurity level, three one-kilogram samples were passed through each unit. Each one-kilogram sample was prepared with specific quantities of sound and clean grain, light materials, foreign materials, broken kernels, and powder.

The analysis of the performance was done on an input-output basis. The data obtained from the tests were analyzed statistically in order to determine the differences between efficiency, accuracy, precision, and reproducibility of the three models.

The Labofix model had the highest overall removal efficiency and the highest removal efficiency of broken kernels, the N.S.L. had the highest removal efficiency of light materials, and the XT3 the highest removal efficiency of foreign materials.

The effect of moisture content was greater on the performance of the XT3 than on the Labofix and N.S.L. models. The effect of impurity level was also greater on the XT3 than on the Labofix and N.S.L. models

Labofix had the highest precision and an average coefficient of variance of 5.69 percent. The coefficient of variance for the XT3 and N.S.L. units was greater than 10 percent.

The XT3 had the highest reproducibility. The XT3 was less affected by the unit effect and replicates effect than Labofix and N.S.L.

Labofix removed more impurities than was reported for duplicate samples inspected by the Kansas Grain Inspection Service.

Labofix was the most applicable model for grading the five crops investigated.

A more efficient system for grading grain could be designed by combining the best features of each model tested.