INCREASING DRYING RATE OF ALFALFA AND REDUCING AMOUNTS OF CROP LOSSES

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PREFACE

This study is concerned with the effect of adding bonding agents to hard crushed alfalfa on the drying rate of alfalfa and reducing amounts of crop losses. It was financed by the Oklahoma State University Agricultural Experiment Station under Regional Project No. G-1627, "Equipment and Techniques to Increase Quality, Productivity and Efficiency of Year-Round Forage Systems." I am very grateful to the Agricultural Engineering Department for providing financial support for the study and for providing me with a research assistantship as well.

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LIST OF SYMBOLS

A	correction factor defined in Equation (2.5)
C	material constant
EXP	exponent to the base of natural logarithm
Hr, hr	hour
K	drying constant, Hr^{-1}
M	instantaneous moisture content, percent dry basis
M_e	equilibrium moisture content, percent dry basis
M_o	initial moisture content, percent dry basis
MR	moisture ratio, defined in Equation (2.2a)
n	material constant
rh	equilibrium relative humidity, a decimal
T	temperature, °R
VPD	mean saturation vapor pressure deficit, millibar
W_b	weight of hay batting sample, prior to running it through the pickup unit
W_ℓ	weight of lost material (the portion of hay batting which was not picked up by the pickup unit)
$(\alpha = x)$	statistical significance level, x = probability of type I error
θ	elapsed time, hour

CHAPTER I

INTRODUCTION

Relevance of the Research

Hay is the most important harvested feed for livestock; average annual production in the United States is about 130 million metric tons. In the state of Oklahoma, there are approximately 0.72 million hectares of cultivated land used for producing hay crops. The market value of hay produced from this land was estimated at slightly over 210 million dollars in 1977 (Agricultural Statistics, 1978).

Alfalfa, sometimes called the "queen of the forage," is one of the most important forage plants in the United States. It has the highest feed value of all commonly grown hay crops. Alfalfa produces more protein per hectare than any other crop for livestock (Dale et al., 1978). In 1977, about 1.2 million tons of alfalfa were harvested in Oklahoma. This amounts to about 40 percent of the total harvested forage (Agricultural Statistics, 1978).

If harvested and handled properly, alfalfa will produce two and one-half times as much protein per hectare as soybeans, two times as much protein as corn silage, and three times as much protein as shelled corn (Dale et al., 1978). Economically alfalfa competes well with the grain crops.

Just these few references are adequate to indicate the importance of alfalfa as a cash crop and a high protein feed. A major limiting factor in alfalfa production is the losses caused by the mechanical harvesting operations and bad weather.

In the curing of high quality hay, proper drying of the crop has been an important consideration, because in humid regions it is difficult to completely field cure the forage without some rain or dew damage. Rains reduce the quality of hay by leaching the nutrient and by bleaching. The loss of feed value, in weather-damaged hay, can vary from 25 to 40 percent (Kurtz et al., 1968), and is a major concern to forage producers. Quality is also reduced through extra handling, causing leaf and stem losses.

Freshly cut alfalfa is a living material, since the plant cells continue respiration and plant enzymes are active as long as air is present and there is sufficient moisture available. Losses of dry matter amounting to 5 to 15 percent of the total crop have been found to occur from these fermentation losses during normal field drying (Pederson et al., 1960).

During the period of curing alfalfa hay, the rate of moisture loss from the leaves is more rapid than the rate of moisture loss from the stem. The principal impediment to rapid drying lies in the geometry and structure of the plant stem. The leaf has a large area with numerous openings relative to its volume. The stem is roughly a circular cylinder, giving a small surface area, and is covered with a more impervious epidermis and cuticle perforated with fewer stomates (Bagnall et al., 1970). This characteristic difference in the rate of drying of two constituent parts of the plant results in overdry leaves, while the stem contains more moisture than is safe for storage, normally 25 percent (dry basis). By the time the moisture content of the stems is lowered to 27 to 33 percent, that of the leaves may be as low as 12 to 14 percent. When the leaves become overdry, they are susceptible to shattering loss in the ordinary process of taking the hay into the storage.

Salmon et al. (1925) reported that over seven seasons of cutting, an average of 19 percent of the leaves were lost when alfalfa hay was harvested by mowing, natural curing, and raking. This figure was considerably larger when the hay received one or more rains while still in the field. In this connection, it should be stated that the leaves are the most valuable parts of the hay crop. Although leaves make up about 50 percent of the dry matter, they contain approximately 75 percent of the digestible protein, 90 percent of the carotene, 60 percent of the digestible dry matter, but only 25 percent of the crude fiber in the whole plant (Bohstedt, 1944).

Because of weather risk and increased loss of carotene, protein, and dry matter with extended field exposure, the time interval between cutting and storing of alfalfa hay should be reduced to a minimum and the slower drying rate of the stem should be speeded up to approach that of the leaves.

A great deal of progress has been made in the development of forage conditioners. In common usage, the term "hay conditioning" refers to any form of mechanical treatment of freshly cut hay in the field that is used to increase the natural drying rate. The conditioners crack the hay stem, exposing more area for moisture loss and thus speed the field-curing rates of forage crops. The present commercial conditioners may be put into two general classifications: the corrugated roll (crimper) and the smooth roll (crusher). The crimper, because of its corrugaged rolls, cracks the stem at regular intervals while the smooth-roll unit crushes the stem along its entire length. Tests at a number of agricultural stations have demonstrated that hay crushed immediately after mowing dries considerably faster than untreated hay. Laboratory tests with various mechanical, chemical, thermal, and electrical treatments applied to alfalfa indicated that crushing the stems to increase the amount of exposed surface is one of the most effective ways to increase the drying rate (Priepke and Bruhn, 1970). Pedersen and Buchele (1960) found that only when the stem surface was nearly disintegrated by hard crushing (so severe that it caused juice to appear on the stem surface) did the rate of evaporation for the stems approach that of the leaves.

Bruhn (1955) found that the drying rate is essentially in direct relation to the degree of crushing. He indicated that up to a certain point, roll pressure very definitely affects the drying rate unless other factors mask out the pressure effects. Observation of potential clipping losses (the clipping was indicated as the precent of separation of leaves and small stems determined by screening the sample through a 51 mm mesh poultry netting) and of actual losses by picking up missed material after windrowing and baling indicated that losses due to conditioning with a mower-conditioner may be greater than from mowing without conditioning by 1 to 4 percent of the yield (Kepner et al., 1960). Crushing alfalfa under high pressure, 5.3 kg per centimeter of roll length (30 lb/in.), results in an extremely high drying rate, but it has little practical value because of excessive clipping losses during subsequent handling (Bruhn, 1959). While not all of the clipped leaves and stems will be lost during pick up of the cured crop, it is logical to believe that the losses will be essentially in proportion to the clipping.

To make this method of harvesting (crushing under high pressure) practical, a method of curing hay in the field should be designed to reconstitute the crushed crop back into a windrow in a form that will save all the leaves and promote rapid curing to reduce the possibility of rain damage. This would be done by hard crushing and then binding all components of the treated crop together. The sticking of the separated leaves and small stems may be accomplished by bonding agents and pressure. Numerous binders are available and several have been tested for their effect on rice straw cubability (Waelti and Dobie, 1973). Dobie (1975) reported that most grasses cube reasonably well with the addition of 5 percent of a good binder, provided it is well distributed on the material. The more difficult-to-cube grasses may require 7.5 percent of binder to produce good cubes.

Dry binders can absorb some of the juice resulting from hard crushing of alfalfa stem and may make a batting that will hold all components of the hay together during field curing ahd during baling. Information on the effect of binders on drying rate and final form of hard crushed alfalfa is needed for designing more effective forage harvesters. Specific information on this topic is not available. The present study was undertaken to obtain information on the effects of adding binders to hard crushed alfalfa on the drying rate of alfalfa and reducing crop losses.

Objectives

The specific objectives were as follows:

1. To evaluate the effects of hard crushing on drying rate of alfalfa and clipping losses of leaves and small stems.

2. To investigate the possibility of making a continuous batting

from hard crushed alfalfa (including separated leaves and small stems) by applying different bonding agents and pressures.

3. To evaluate the drying rate and durability of the forage batting as influenced by combinations of roll pressure, binder type, and binder concentration.

CHAPTER II

REVIEW OF LITERATURE

Hay is grown on more than one-half of all the farms in the United States, with the area averaging about 20 percent of the total harvested crop land. Forage harvesting and handling is complicated by the nature of the product. Hay is a crop of great bulk and may contain 65 to 85 percent water when harvested. For storage, it must be dried, either naturally or artificially, to a safe moisture content of 20 to 25 percent (dry basis). Long loose hay or extremely loose bales can tolerate slightly higher moisture content without serious damage.

Alfalfa is often a difficult crop to harvest because of the differential drying rate of the leaves and stems. By the time the stems have reached a moisture level sufficient for storage, the leaves have been overdried. This excessive drying of the leaves only serves to increase shattering losses in subsequent operations. The possibility for harvesting high-quality hay in humid regions is generally low, because the period of time between rains is less than the time required to cure, harvest, and store the hay.

Traditionally, the substantial difference in leaf and stem drying rates has led to many attempts to increase the drying rate of the stem. For example, stems have been subjected to mechanical dewatering (Chancellor, 1964), heat blanching (Thompason, 1952), hot water blanching (Chancellor, 1964), steaming (Byers and Routley, 1966), removal of epidermis or cortex (Bagnall et al., 1970), twisting, chopping, and crushing (Pedersen and Buchele, 1960). The principal objective of all methods was to decrease the field curing time and thus minimize the possibility of loss due to bad weather.

Mechanical Treatment

Tests at a number of agricultural research stations have demonstrated that hay crushed immediately after mowing dries considerably faster than untreated hay. Geographic location also tended to have a bearing for some mechanical treatments on their hay drying rates.

Early development work with forage crushers, as a means of accelerating the drying rate of alfalfa, was conducted in California (Bainer, 1931) during the early 1930's with a machine designed and constructed by E. B. Cashman. The early machine was a self-propelled unit and consisted of a platform and draper very similar to those found on the ordinary grain binder of that period with a set of rubber-covered steel rolls. The lower roll was held rigidly in place while the upper roll floated under tension provided by two springs. Two revolving brushes tended to keep the rolls free of any crushed hay. Ten hours after cutting with this machine, the crushed hay contained 23 percent moisture (wet basis) while the regular cut hay contained 46 percent.

Reed (1932) found that crushed soybean hay dried very rapidly and that in 2.5 hours it had reached a moisture content of 30 percent (wet basis), while the uncrushed sample still contained 34.7 percent moisture at the end of 14 hours.

Zink (1933) obtained similar results by passing the alfalfa between two rolls which were held in contact with each other by means of springs. One of the rolls was made of steel while the other was of steel covered with rubber. He reported that the crushed alfalfa had reached a moisture content of 25 percent 4 hours after cutting, while the uncrushed hay had not yet reached 25 percent moisture content until on the second day or about 23 hours after cutting. The process provided for a more equal drying rate of leaves and stems, and increased the drying rate by stem bleeding and by increased evaporation through the stem fractures. Although Zink reported that under eastern Kansas conditions crushing appeared to insure a moisture content sufficiently low to permit storage of alfalfa hay the same day that it was cut, little acceptance of the crushing method was noticed until the middle fifties.

In 1926, an investigation was made of the relation of the drying rate of alfalfa leaves and stems (Kiesselback and Anderson, 1926). The results indicated that under laboratory conditions, first cutting alfalfa hay, when at 20 percent moisture content, was composed of leaves containing 12 percent and stems containing 27 percent moisture. Zink (1933), under field curing conditions, obtained similar results. He found that when there was 30 percent moisture within the hay, the leaves had only 16 percent while the stems had 38 percent.

By crushing large-stemmed hay, such as Johnson grass and sudan grass, Jones and Dudley (1948) found the time required for field curing could be reduced from one-third to one-half that of crushed hay. They observed that the moisture content of uncrushed sudan grass was not low enough to bale until the morning of the fourth day, or 72 hours after it was cut, while the crushed required only 27 hours to cure and was baled on the second day after cutting. They also indicated that the leaves of uncrushed hay were overcured and shattered before the stems cured.

A study made by Bruhn (1955) of alfalfa indicated that high pressure, high roll speed, multiple rolls, operating the second set of rolls slower than the first set and feeding the material to be crushed into the rolls in a very thin uniform layer all contributed toward more effective crushing and higher drying rate. He found that the forage fed once through the machine with two sets of rolls had dropped to 25 percent moisture in a little over four hours, and that which made an additional pass through the two sets of crushing rolls dropped to 25 percent moisture in about three and one-half hours. He also pointed out that two pairs of crushing rolls operating at moderate speed, pressure, and rate of feeding produced a drying effect comparable to one pair of rolls operating at high pressure, high speed, and low rate of feeding. However, the two pairs did less damage to the crop in the way of clipping and stripping than the one pair when operated for high performance. The results also indicated that operating the second pair of crushing rolls slightly slower than the first pair seems to increase the effectiveness of the crushing with no apparent increase in clipping and stripping losses.

Boyd (1959) conducted field tests to determine the drying rate and field losses of alfalfa and timothy-brome hay which had been conditioned with a crimper, a crusher, or a flail-type forage harvester. Results indicated that flailed material dried at a greater rate than the other conditioned materials. He also reported crushing is somewhat more effective than crimping and it can reduce drying time by about 30 percent. Pickup losses of approximately 7 percent of the total yield for uncrushed alfalfa, 11 percent for crushed and crimped, and 14 percent for the flailed material were reported. Similar results were reported by Sutherland (1959).

Bruhn (1959) Studied the effect of delay in the crushing operation and indicated that delaying the crushing just meant a drying rate similar to uncrushed material during the delay and then a drying rate after crushing comparable to crushed material of the same moisture content. Double crushing with a delay between the first and second crushing produced a very high drying rate with a considerable jump at the time of second crushing. He also reported that the clipping of leaves and small stems from the main stem was inversely proportional to the rate of travel and the thickness of the mat of material passing between the rolls, and the increased drying rate was in direct relation to the clipping.

Casselman and Finham (1960) compared the field-drying rate of alfalfa hay which had been flail-cut, mowed and crimped, or just mowed. The flail-cut material, which was placed in windrows by the flail unit, dried to 20 percent moisture content (wet basis) in 28 hours, whereas the crimped alfalfa required 53 hours and the untreated about 77 hours.

Similar work has been carried on with a crusher and crimper in California (Kepner et al., 1960). The results indicated that, in general, conditioning usually reduced the field curing time by about two days. They pointed out in the second cutting, however, showers occurred after the conditioned hay had been baled and while the control was still in the windrow, thus increasing the difference in curing time to four days. They also reported that field losses due to conditioning exceeded those without conditioning by an average of 1.1 percent of the crop with the crusher and 3.6 percent of the crop with the crimper.

By applying different treatments to the alfalfa plant, Pedersen and

Buchele (1960) concluded that faster drying was obtained when the stems were hard crushed or when the stems were penetrated several places per inch of length. Lower rates were recorded when the stems were twisted, crushed, or cut in pieces of 2 inches in length. They also reported that as hard crushing was applied, the stem dried faster than the leaves. It is thus evident that a complete breakup of the cuticle causes the stems to dry faster than the leaves.

A laboratory experiment was conducted by inserting a vapor barrier between the hay and the soil. Results indicated that the effects of evaporation from wet soil was eliminated and the time necessary to dry the hay to storable conditions was reduced. They also pointed out that hay mowed before 10:00 a.m., crushed, and placed on black polyethylene sheets, dried to a storable moisture content of 20 percent (wet basis) before 4:00 p.m., and was harvested the same day as cut.

Fairbanks and Thierstein (1966) reported that crushing the alfalfa probably increases the rate of carotene losses during field curing; however, because of the increased rate of drying and reduced drying time, the carotene content of the crushed hay at time of storage will be equal to or higher than that resulting from other conditioning treatments. They also indicated that alfalfa may be cut, conditioned by crusher, and baled the same day in eastern Kansas when weather conditions are satisfactory.

Geographic location appeared to have an effect on the flail mower treatment. Hall, working in Ohio (1964), found hay with that treatment dried quicker than crushed hay. However, Kurtz and Bilanski (1968) found dissimilar results in Canada. They reported that the quickest drying rate was demonstrated by the alfalfa hay which was treated by the mow-crushed process.

Hellwig (1965) indicated that the rotary mower severely altered the physical form of bermudagrass and gave a more rapid rate of drying than the crusher or crimper. However, the loss of one-half or more of the yield made this method undesirable for making hay.

Single stem samples were scraped with a sharp knife (Bagnall et al., 1970) and dried to determine the effect of removal of the surface layer of cells on drying rate. Light scraping removed the translucent epidermis and heavy scraping removed the bright green cortex. The drying rate for lightly scraped samples was significantly higher than that for controls, and the drying rate for heavily scraped samples was higher than for the lightly scraped samples and controls. He concluded that principal restriction to stem drying is in the epidermis and cortex, and that complete removal of these can substantially increase the drying rate.

Barrington and Bruhn (1970) investigated the effect of existing mechanical forage harvesting devices on field curing rate and relative harvesting losses, and reported that roll-type crushers were highly successful in increasing the field drying rate of both alfalfa and hybrid sorghum sudangrass. Harvest losses resulting from use of these machines were relatively small. They also indicated that conditioning a forage crop with flail mower-type equipment can result in a high drying rate, but usually also results in a high harvest loss.

Under laboratory conditions, four sets of different types of crushing rolls were evaluated by Straub and Bruhn (1975). They concluded while increased pressure tends to increase drying rate when both rolls are driven, it may tend to have a negative effect if only one roll is driven. They also reported that conventional rolls (spiral steel bar roll against a ti-cord roll) did poorest at low roll pressure. However, as roll pressure was increased, both the conventional rolls and ti-cord rolls produced a treatment which gave faster drying rates than the rubber-coated intermeshing rolls.

The objective to increase drying rate and digestibility of coastal bermudagrass was achieved by a tandem roll mower crusher (Hellwig et al., 1977). They indicated that in the southeastern United States, one day saving in drying time may be the difference between recovering 90 percent of the hay and losing all of it.

The effect of five different types of forage conditioning rolls, two levels of treatment (one or two passes of material), and three levels of feed rate on the drying rate of alfalfa hay were investigated under laboratory conditions (Aviki and Batchelder, 1979). The results indicated that:

1. The most effective type of roll was the steel crimper roll that on the average dried hay about 1.75 hours faster than plastic cord roll treated hay.

2. Alfalfa hay treated twice dried about 0.5 hours faster than that treated only once.

3. An increase in feed rate generally resulted in an increase in drying time required for all rolls except for the plastic cord rolls.

4. Under simulated conditions harvesting alfalfa in one day, even for the best treatment, was not possible.

Chemical Treatment

Tullberg (1965) investigated the use of a chemical agent to keep the stomata open and studied the effects of this treatment on drying rate. Alfalfa samples were treated with sodium azide 0.0005 in tartrate buffer 0.01 m, pH 4.5, both by immersion and spraying. It was found that this treatment kept stomata open to an average width of 4 μ at 40 percent moisture content, while untreated samples had closed stomata at 60 percent moisture content. Whitney et al. (1969) found that leaves with stomata open to any extent dried significantly faster than did those with completely closed stomata.

By use of sodium azide as an agent to promote the drying rate of alfalfa, Mears and Roberts (1970) found that in low temperature tests all drying rates were increased with the treatment and increases became more pronounced at higher moisture contents. It must be pointed out, however, that sodium azide is toxic and the residual material in the drying alfalfa may be dangerous.

A chemical treatment was applied by dipping the cut alfalfa into an analytic reagent grade of carbon tetrachloride for a few seconds (Priepke and Bruhn, 1970). The solvent seemed to have an effect on the fatty acid esters which are the basic component of cutin. This allowed more water to be removed from the alfalfa in the first drying period when compared to the untreated samples. The drying rate was also increased due to the lower resistance of exposed surface to water movement. They reported that the drying rate of alfalfa, crushed and then dipped in a carbon tetrachloride solution for a few seconds, was much greater than that obtained when each treatment was applied individually.

Tullberg (1976) treated lucerne by rapid immersion in potassium carbonate solution under laboratory conditions. Results indicated that the maximum drying rate occurs at concentration in the order of 0.18 m.

Increased potassium carbonate concentration did not result in further increases in drying rate using this treatment method. In field experiments done by Tullberg again, the results have supported the laboratory results. He found that hay treated with heavy application (300 liters per hectare) of 0.18 m potassium solution will dry more rapidly than that subjected to severe mechanical conditioning. At lower application rates (200 liters per hectare) the potassium carbonate treated hay was significantly drier than untreated material, and also appeared to be substantially drier than hay cut by mower-conditioner.

Furthermore, chemicals have been applied to reduce the field curing time by increasing the maximum allowable moisture content for safe storage. Alfalfa hay baled at 32 percent moisture content (wet basis) was treated with anhydrous ammonia at one percent level of the weight of the hay and lost 5.2 percent less dry matter than did untreated alfalfa (Knapp et al., 1975).

Manby and Shepperson (1975) applied propionic acid at a two percent level by weight and concluded that if it can be uniformly distributed, it will inhibit mold development on hay having up to 35 percent moisture content.

Similar results have been reported by Bush (1977). He indicated that an application of 70 percent propionic acid plus 30 percent formalion at a rate of one percent of the weight of the hay and with the hay stored at 30 percent moisture content will result in a quality approximately equal to that of any baled hay under ideal conditions.

Heat and Steam Application

Alfalfa stems were subjected to heat blanching by Thompson (1952).

The results showed that heat blanching of green alfalfa speeds the sun drying rate by increasing the rate of water loss, and preserves carotene. It also gives a product in which carotene is more stable than in ordinarily dried material and probably preserves nutrients ordinarily lost by respiration after cutting.

In a study conducted by Byers and Routley (1966), the alfalfa samples were crimped or steamed-crimped immediately after cutting. The results indicated that steaming speeds the movement of water from alfalfa. Crimping plus steaming further increases the initial drying rate, while after a limited time drying rate increases. This indicates that the drying rate is limited to the decreasing permeability of the cell wall cytoplasmic membranes and stomata action.

Preliminary tests were conducted to determine the effectiveness of applying an open flame to alfalfa on field drying time (Person and Sorenson, 1970). Application of a flame to standing plants or to plants after they had been cut resulted in a significant reduction in drying time.

Similar work has been carried on by Priepke and Bruhn (1970). They reported that for the heated plants, because of initial water evaporation, the initial drying rate was higher than untreated samples. They also pointed out that the improvement of drying rate can be attributed mostly to surface alteration.

Heated rolls were used to crush the alfalfa at 182°C and 138°C (Priepke and Bruhn, 1970). The results showed that about 18 percent of the water was evaporated during the treatment by the heat from crushing apparatus. The main effect of this treatment was the crushing, but indication at the 182°C level was that the drying was improved by the heat affecting the alfalfa's physical structure. They concluded that the heat may have had the effect of melting the cutin to expose some of the stem surface which has less drying resistance.

A report by Priepke and Bruhn (1970) evaluated the effect of microwave treatment on drying rate of alfalfa. The samples were first crushed and then placed in a commercial household microwave oven for five seconds. The results indicated that the drying rate of alfalfa samples with this treatment was greater than that obtained when each crushing or microwave treatments were applied individually.

Hot Water Blanching

In a study conducted by Chancellor (1964), chopped alfalfa was immersed three seconds in boiling water and then the blanched material was placed between two flat plates and pressure applied. With this method he removed up to 83 percent of the water content from alfalfa while about 15 percent of the dry material was lost.

Bagnall et al. (1970) reported that immersion of stems of alfalfa for three to twenty seconds in water at 60 or 93°C increased the drying rate of the stem while other temperatures and exposure times had no significant effect. They also indicated that hot-water blanching did not increase the drying rate sufficiently to justify the cost of time and equipment, especially when water absorbed during blanching was considered.

In another test, the blanching treatment was performed by dipping the cut alfalfa into boiling water for ten seconds (Priepke and Bruhn, 1970). The results indicated that the samples took in 28 percent more water than was originally in the alfalfa during the treatment which greatly delayed the drying time even though it had a higher drying constant. They pointed out that the hot water blanching may have softened the surface, lowering its resistance to water movement, or the heat may have broken down proteins, lowering their water holding capacity.

Crop Losses

The loss of leaves while curing and handling accounts for a considerable loss of nutrient value of the final product. The amount of leaf loss is extremely variable. It is influenced by a number of factors, or combinations of factors, depending both on the machine used in hay making and the climatic conditions while the hay is being handled. The loss of leaves has been noted by many investigators. Salmon et al. (1925) found that in over seven seasons of cutting, including four stages of maturity in each of the subsequent crops, an average of 19 percent of the leaves was lost. This loss was found to vary from 2.3 percent to as much as 34 percent. In this study the leaves represented 51.1 percent of the crop at the one-tenth bloom stage.

Zink (1936) observed the field drying rates of leaves and stems and concluded that as alfalfa hay approaches 30 percent moisture (wet basis), there is considerable danger of losing the leaves. He also indicated that leaf shattering occurs when they approach an air dry condition of approximately 10 percent moisture and apparently have a rather narrow range of moisture content when they are susceptible to separation from the main plant.

Shepherd et al. (1947) calculated yield totals for different hay management systems at different times during the harvest system. They mowed the alfalfa at quarter bloom, it was rained on twice, and baled it at 20 percent moisture content. They indicated that 36 percent of dry matter was lost during this process.

Daum (1958) has shown that the strength of attachment of alfalfa leaves to the stem is influenced by the moisture content of the stalk, with the force necessary to remove the leaf from the stem decreasing rapidly below a stalk moisture content of approximately 40 percent (wet basis).

An extensive review of losses is contained in Hall's book (1957). He reports losses in field cured hay ranging from 23 percent under the most favorable condition to 54 percent. According to the USDA (1954), the total loss of hay crop in the United States is 650 million dollars per year.

Losses of 5 to 15 percent of the dry matter have been found to occur from respiration and enzyme action during normal field curing (Pedersen and Buchele, 1960).

Field losses were compared between the flail-cut and crushed portion of the field on second cutting alfalfa by Hall (1964). He reported that the losses for the flailed alfalfa amounted to 14.1 percent of the total yield and the loss for the crushed alfalfa was 11.6 percent of the total yield.

A study was made by Vigiva Raghavan and Bilanski (1973) to find the effects of tension, bending, impact, and vibration on alfalfa leaf loss for different moisture contents at different stages of maturity. Overall results indicated an increase of leaf loss due to mechanical forces at low moistures and older stages of maturity of the plant.

Dale et al. (1978) developed a computer simulation model (Hayloss) of alfalfa harvest losses incorporating the effects of climatic information, plant species, and different machinery systems. Using the same input data as Shepherd et al. (1947), hayloss gave a 34.2 percent total harvest loss as compared to 36 percent for Shepherd's data.

Drying Mechanism

The mechanism by which moisture is moved from biological materials has been described by Barre (1938). Moisture will move as a vapor from regions of higher partial vapor pressure to regions of lower partial pressure. The rate of this movement is proportional to vapor pressure gradient and inversely proportional to the resistance to vapor movement. Thus, the process can be considered one of diffusion. To increase the drying rate, it is necessary to increase the vapor pressure gradient or decrease the resistance to vapor movement. Heat and mass transfer principles show that the shorter the distance through which the moisture diffuses, the greater the moisture diffusion rate will be. In an alfalfa stalk, this distance is shortened by conditioning the stalk in such a way as to split the stalk longitudinally. Thus, more of the stalk is exposed to the drying medium and the distance through which the moisture must diffuse is reduced due to splitting of the stalk (Hall, 1964).

Studies of the drying rate of biological materials have shown that the rate of drying is proportional to the differences between the final equilibrium moisture content and the instantaneous moisture content. Mathematically, this is given by:

$$\frac{dM}{d\theta} = K(M - M_e) \quad (2.1)$$

after separating variables and integrating within proper limits, the solution is obtained as:

$$MR \text{ (moisture ratio)} = EXP\ (-K\theta) \quad (2.2a)$$

and

$$MR = \frac{(M - M_e)}{(M_o - M_e)} \tag{2.2b}$$

where

M = instantaneous moisture content of material, dry basis;

M_e = equilibrium moisture content, dry basis;

M_o = initial moisture content, dry basis;

K = drying constant; and

θ = elapsed time, in hours (Hall, 1957).

An alternative form of the equation often used is

$$MR = EXP\ (-K\theta^n) \tag{2.3}$$

where both n and K are material constants (Hill et al., 1977). They used this equation to predict drying time of alfalfa and concluded, under conditions of steady vapor pressure deficit, the moisture ratio of drying alfalfa could be represented at any time θ as

$$MR = EXP\ (-K\theta^{0.8}) \tag{2.4a}$$

where

$$K = 0.007\ (VPD) + 0.1164 \tag{2.4b}$$

and VPD is mean saturation vapor pressure deficit expressed in millibars.

A correction factor "A" is usually incorporated in Equation (2.2a) for better agreement with drying data, and the equation of this simple model, as mentioned by Henderson and Perry (1966), becomes:

$$MR = A\ EXP\ (-K\theta) \tag{2.5}$$

where A and K are experimentally determined for particular applications.

Based on the empirical observation, it is known that the moisture content of a biological material asymptotically approaches its equilibrium with a given environment. Henderson and Perry (1966) have used a general formula to relate the variables in the equilibrium moisture relationship for a number of biological materials. The expression is:

$$1 - rh = EXP\ (-cTM_e^n) \tag{2.6}$$

where

rh = equilibrium relative humidity, a decimal;

T = temperature, °R;

M_e = equilibrium moisture content, dry basis; and

c,n = constants which depend upon the material and the temperature.

Hill et al. (1977) determined the equilibrium moisture content for alfalfa at different relative humidities and from that calculated the values of constants c and n for alfalfa to be 0.851×10^{-4} and 1.013, respectively.

CHAPTER III

MATERIALS, EQUIPMENT, AND METHODS

Fresh Hay Supply

Alfalfa grown on the Oklahoma State University Agricultural Experiment Station farm near Chickasha was harvested by a Jarri mower. The cut material was approximately 25 cm long. An area of about 580 square meters of alfalfa was selected and divided into seven equal plots to supply fresh hay for seven days of experiments. This was a second cutting for this hay.

In order to provide the same age alfalfa plant for repeated runs of the different treatments, each plot was harvested about 30 days prior to the test to provide alfalfa with the same growth period for each treatment to be run. Harvest for conditioning tests was done when alfalfa was at about 1/10 bloom.

For a typical day's run, a plot of alfalfa was mowed after the dew had evaporated. The harvested alfalfa was placed into a box and covered by plastic to prevent moisture losses during handling from the field to the conditioning laboratory.

Bonding Agents

Numerous binders are available; two different bonding agents (Orzan G and Nutri-Binder) were used to hold all components of crushed alfalfa in this series of tests. Orzan G was previously determined to be among the most effective of those bonding agents tested by Waelti and Dobie (1973). Dobie (1975) reported that most grasses cube reasonably well with addition of 5 percent of Orzan G, provided it is well distributed on the material. The more difficult-to-cube grasses may require 7.5 percent of Orzan G to produce good cubes.

Orzan G is a light brown powder, an organic spray-dried lignin extract consisting chiefly of ammonium lignin sulfonate, wood sugars, sulphur, and nitrogen in the form of ammonia. It is completely soluble in water and its solution does not settle upon standing. A typical composition of Orzan G used is shown in Table I.

TABLE I

SOME PHYSICAL AND CHEMICAL PROPERTIES OF ORZAN G*

Solids Content by Oven Drying, %	95.0
pH, 25% Solution	5.0
Bulk Density, kg/m^3	496.2
Base Displaced Ammonia, % NH_3	5.3
Total Nitrogen, % N_2	5.2
Reducing Sugars, % as Glucose	8.0
Total Sulfur, % S	6.0
Ash, %	2.0
Sodium, %	0.3
Calcium, %	>0.1

*Information adapted from product information bulletin, Crown-Zellerbach, Camas, Washington (1977).

Nutri-Binder is a product of Progressive Grain Processing Corporation made for animal feed manufacturers. It is a tan colored powder containing principally grain products with 8 percent protein, 2 percent fat, and 3 percent crude fiber.

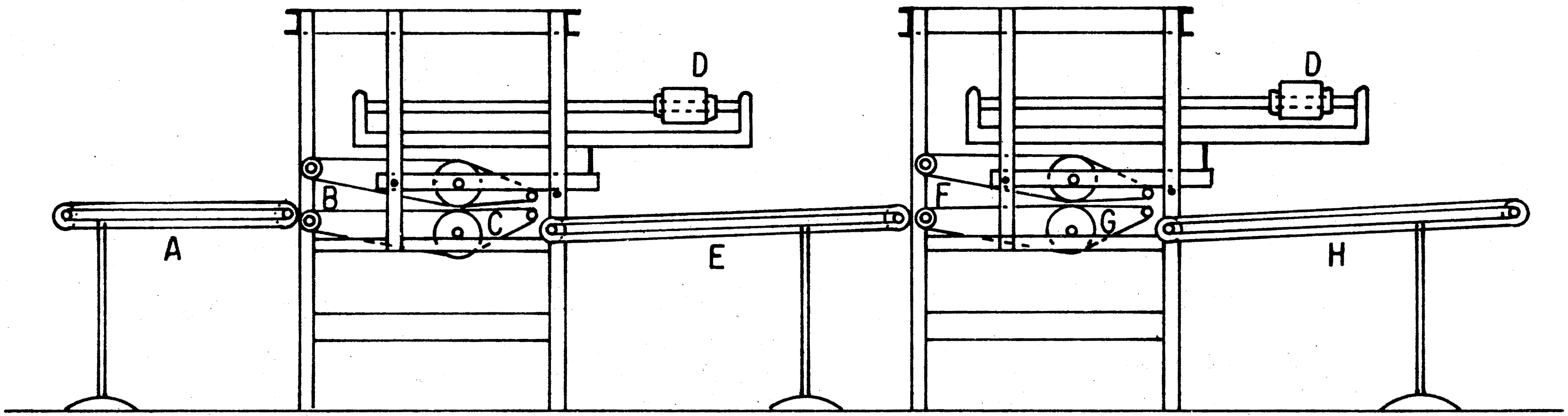
Equipment and Facilities

Conditioning System

The existing conditioning system, designed by Batchelder et al. (1979), was modified by adding two pairs of feeding belts, a mixing device, bonding agents distributor, and eliminating the stainless steel conveyor chains. A brief description of the system is presented below.

The conditioning system consisted of a pair of conditioning roll stands (Figures 1 and 2). A pair of smooth steel rolls 20 cm in diameter by 45 cm long were mounted in each stand in such a manner that material could be fed horizontally. The lower roll position was fixed, while the upper roll was mounted on pivoted members which allowed it to float. Loading was applied by the top roll. Roll pressure was applied by attaching weights to the pivoted upper support. Two 22.6 kg moveable lead weights for each of the roll stands were used. The pipe frame to which the weights were attached could also be moved longitudinally to change the moment which affected the pressure on the upper roll. The roll pressure is expressed in force per unit length of the roll and could be varied from zero to approximately 16 kg per cm of roll length. An adjustable stop was provided to limit the downward movement of the upper roll in relation to the lower roll.

Since the moveable lead weights could not be applied directly above



A. The charging belt
B. The feeding belts
C. The set of crushing rolls
D. The moveable weight
E. The first catching belt
F. The feeding belts
G. The set of batting rolls
H. The final catching belt

Figure 1. Schematic Diagram of the Forage Conditioning System

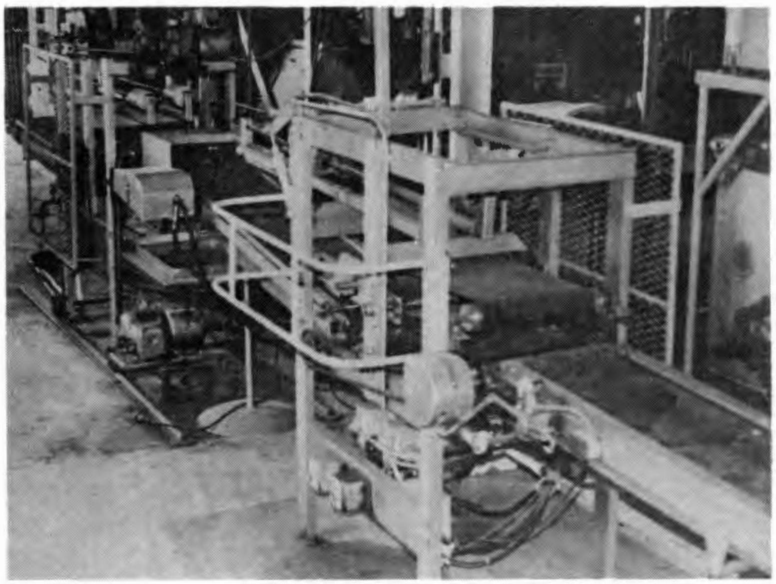


Figure 2. The Forage Conditioning System

the line of contact of the crushing rolls, it was necessary to calibrate the conditioning system to provide different roll pressures. In order to accomplish this, a special lifting frame was designed and attached to the upper roll to determine the forces applied. This frame consisted of a yoke which was hung at its center of gravity from a load cell. The other end of the load cell was attached to a rigid frame. A digital force indicator (Revere, R-100) was used for this calibration measurement. The location of the weight on the pipe frame was marked for different roll pressures so that it was easy to set up the system for desired roll pressure during application of the treatments.

Roll pressures of 12, 14, and 16 kg per linear centimeter of roll length for the first set of rolls (crushing rolls) were applied. The second set of rolls (batting rolls) served to put all components of the crushed alfalfa and the binder together to make a more stable hay batting. The roll pressures for the second set of rolls were 3.5 and 5.0 kg per linear cm. The peripheral velocity of the rolls was 1.3 m/sec. A positive drive for each roll provided for proper matching of rolls at all times and thus did not require that the drive forces for one of the rolls be applied by friction forces through the forage material being fed through the rolls.

The conveying system consisted of five conveyors:

1. Charging belt (A, Figure 1). Forage was arranged on this belt as desired for orientation, quantity, and depth. An air-operated clutch connected the charging belt to the second conveyor chain drive.

2. Feeding belts (B and F, Figure 1) are essentially identical in size and function. Each roll stand has two endless belts which assist in feeding forage through the crushing rolls and prevent losses of crushed

material, especially leaves and small stems. The hay went between the two belts.

3. First catching belt (E, Figure 1). This was used for catching the samples after the first crushing rolls as well as for feeding material through the mixing device after a bonding agent was applied.

4. Final catching belt (H, Figure 1). This conveyor served for receiving the material from the second set of rolls and was stopped for taking samples from the conditioned hay.

The conditioning system is hydraulically driven. A hydraulic power supply unit of 3 liters per second at 10 MPa is shown in Figure 3. An electric motor of approximately 45 kW powered the hydraulic system. The control panel (Figure 4) has switches to turn on, in sequence, the appropriate solenoid-operated valves. These valves supply oil to variable (pressure compensated) flow control valves which in turn control either the conveyor or roll drive hydraulic motors. Four hydraulic motors were used to drive conveyors and rolls.

Shaker

The oscillating screen box (Figure 5) presently used in this study was similar to the system designed by Finner et al. (1978). The screen was a standard 5 cm mesh poultry netting mounted on a 80 cm x 56 cm x 3.5 cm wooden frame. A three-phase electric motor attached to a variable speed drive was used to drive the system. This enabled the speed of oscillation to be varied over a range of 30 to 140 rpm. The shaker served to determine the amounts of crop losses after being crushed at different levels of roll pressure. A tray was placed in the screen box to collect the material passing through the screen.

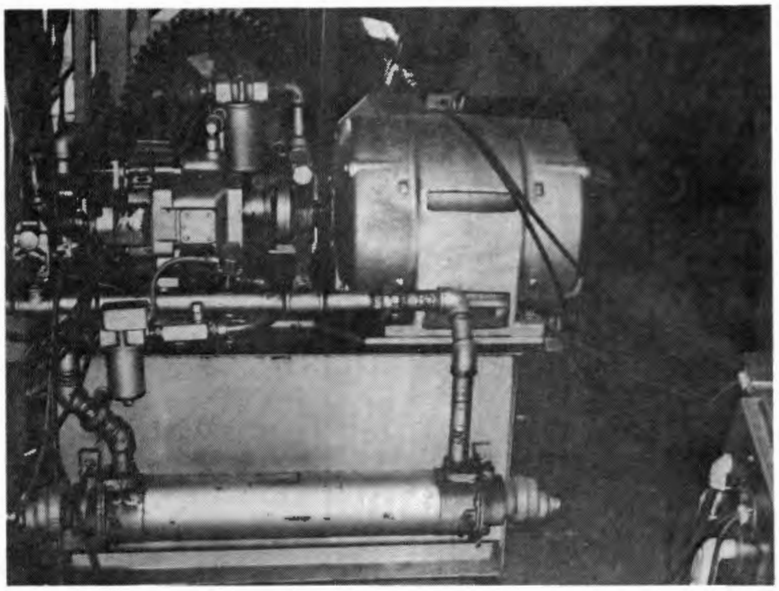


Figure 3. The Hydraulic Power Unit Used to Drive the Conditioning System

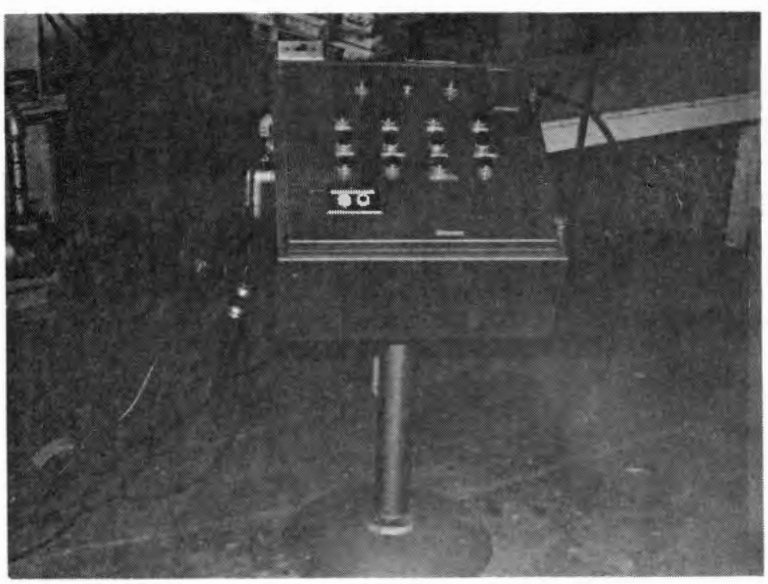


Figure 4. The Hydraulic Control Panel for the Conditioning System

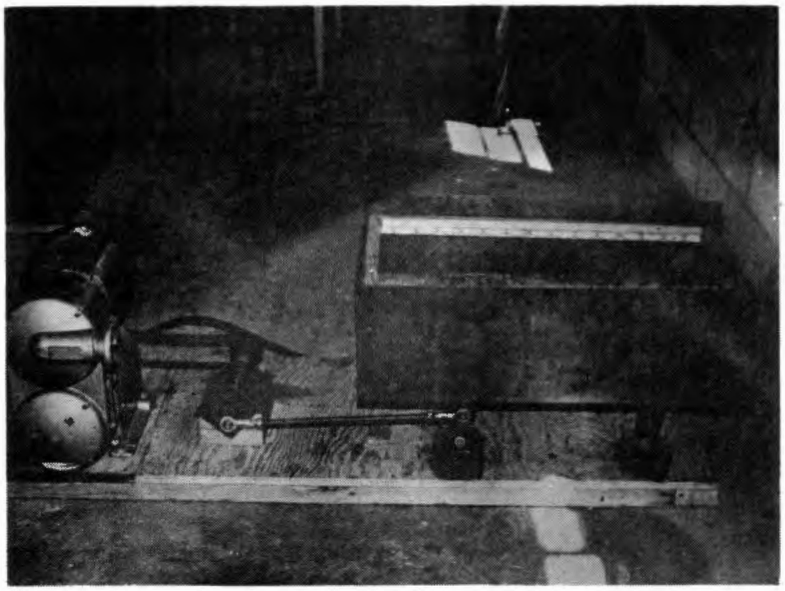


Figure 5. The Oscillating Screen Box to Test Clipping Losses

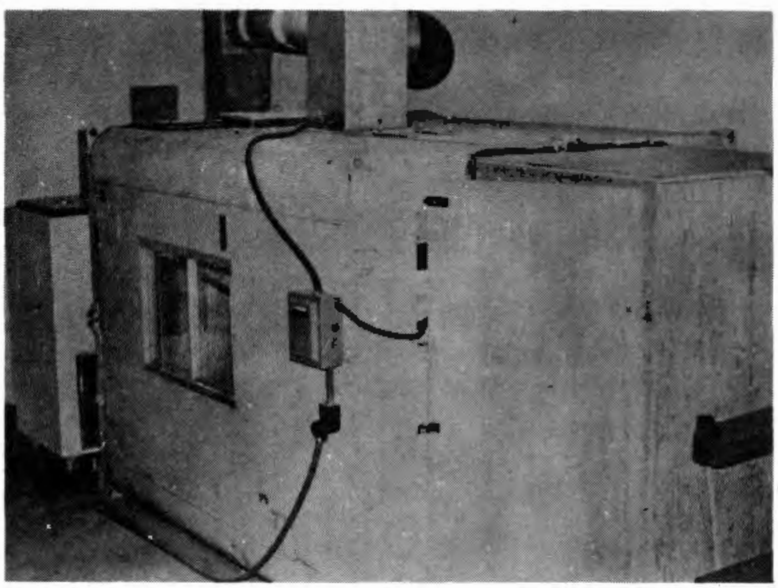


Figure 6. The Drying System: Aminco-Aire Unit (Left), Simulated Ambient Drying Chamber (Middle), and Isolation Entrance Cabinet (Right)

Controlled Environments

Two controlled environments were used in this experiment. A drying chamber was designed to dry 40 samples of alfalfa of 150 grams each, under controlled temperature and relative humidity conditions. A 28.3 cubic meter per minute Aminco-Aire unit for supplying air at controlled temperature and humidity levels was available for the present research work, and it was connected with an insulated environment chamber (Figure 6). The drying chamber had a capacity of 8.6 cubic meters with an overall dimension of 1.93 x 2.44 x 1.83 meters. With the Aminco-Aire unit, the humidity and temperature control is obtained by controlling the water temperature and the air temperature (dry-bulb temperature). To achieve control, air is drawn from the drying chamber through a massive spray of fine water droplets. The water temperature is controlled by a refrigeration heat exchange system. Heat and water vapor are exchanged between the water droplets and the stream of drying chamber air. This continued rapidly until equilibrium is reached and the dew point of air has been fixed. The air is then heated to the desired dry-bulb temperature in another section, and returns to the drying chamber.

The inlet air duct was mounted on the top of the drying chamber and an air diffuser was used to distribute the conditioned air uniformly inside the chamber. The return duct from the drying chamber was connected to the Aminco-Aire unit; thus, the conditioned air was constantly circulated. The rate of airflow was 28.3 cubic meters per minute.

The air and water temperature was controlled by setting the adjustable knobs for air and water on the control panel. Selection of the required water temperature for a desired relative humidity at a given dry-bulb temperature was made using Figure 7.

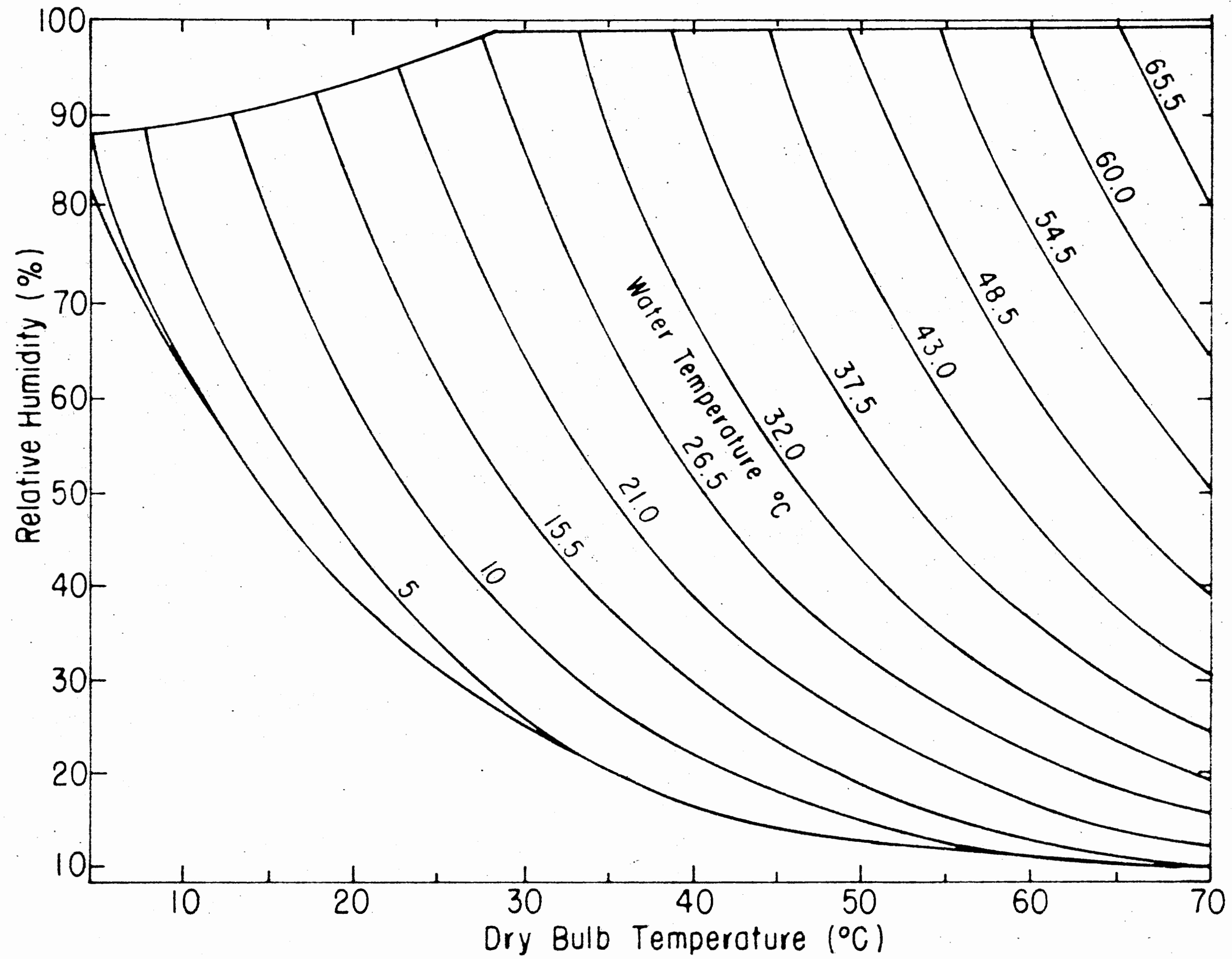


Figure 7. Water and Air Temperature Vs. Relative Humidity for the Aminco-Aire Unit

The loss of conditioned air each time the environment chamber was opened for transferring samples into the chamber was minimized by attaching an isolation cabinet to the front side of the chamber, so that the samples were first carried into the cabinet and then after closing the cabinet door were moved into the drying chamber.

The drying chamber was developed to simulate uniform field drying conditions. The air temperature was adjusted to maintain a mean dry-bulb temperature of 35°C and the water temperature was adjusted to cool the water to about 11°C. This corresponds to a relative humidity of 30 percent, which simulates a good field drying condition typical for Oklahoma.

Drying conditions were kept the same for all treatments so that the relative response, the drying rate, could be determined for each treatment combination.

The temperature and relative humidity level inside the drying chamber were continuously monitored with a pre-calibrated hygro-thermograph in addition to a thermometer installed in the chamber. The controlling mechanism described above could normally maintain temperature levels within ±1°C of the set point, and the relative humidity within ±2.5 percent of the desired level. Any deviation from these limits of temperature and humidity variation was recorded on the hygro-thermograph, and appropriate corrections were made to avoid experimental errors.

For another portion of the study, an air-conditioner and a humidifier were installed in a laboratory room to maintain the air temperature and relative humidity of the room at the desired level. This controlled environment served to store the hay samples taken for a batting durability test and to maintain the samples' equilibrium moisture content at a desired level.

Weighing and Recording System

The weighing and recording system consisted of a chain conveyor with 30 sprockets mounted on a horizontal frame located in the drying chamber to carry the samples to and from the weighing system (Figure 8). A three-phase electric motor drove this endless chain conveyor. Forty-two L-shaped carriers, made of 0.3 cm x 2.5 cm steel flat bar, were welded to the chain conveyor links 30 cm apart from each other (Figure 9). Special moveable hooks were designed to carry the hay samples. The base of the hook was made of aluminum in order to reduce its weight and two small cylindrical magnets were embedded in the base of each hook (Figure 10). The magnets served to hold the hook and sample on the carrier during the transfer of the hay samples to the bottom weighing scale.

The chain conveyor was run with a constant chain speed of 42.5 cm per minute. It took half an hour to complete each cycle. The weighing system consisted of a catcher (Figures 10 and 11) which was hung from an electronic bottom (and top) loading balance. The motion of the catcher during the transferring of the hook and hay sample from the carrier was limited by four adjustable screws which were mounted on a fixed frame.

The weighing sensor (Scientech, Inc. model 222-003) was connected to a control which provides power to operate the weighing sensor and has a digital presentation of weight showing large numbers, easily visible, reading to 1999.9 gr maximum. Full 2 kg tare is instantly available by pushing the tare button on the control.

A calculator interface (Scientech, Inc. Series 202), designed

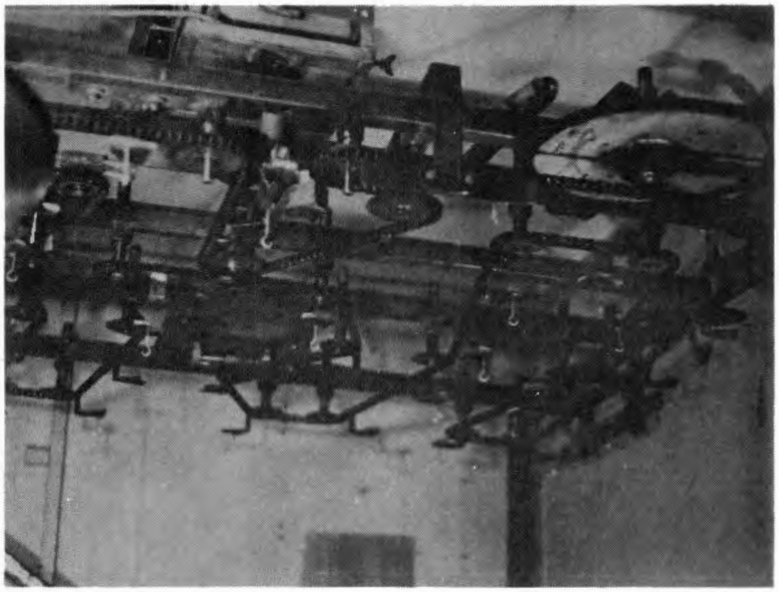


Figure 8. The Chain Conveyor of the Weighing System in the Drying Chamber

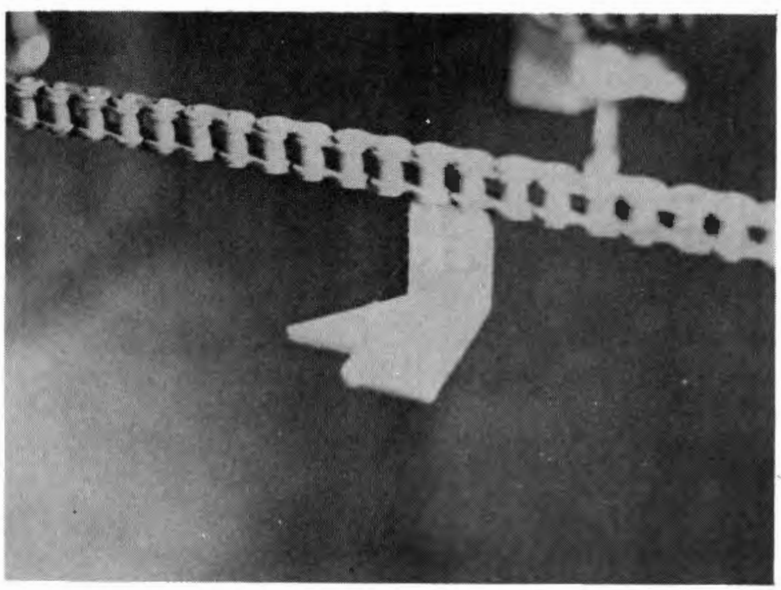


Figure 9. The Sample Carrier, a Component of the Chain Conveyor Weighing System

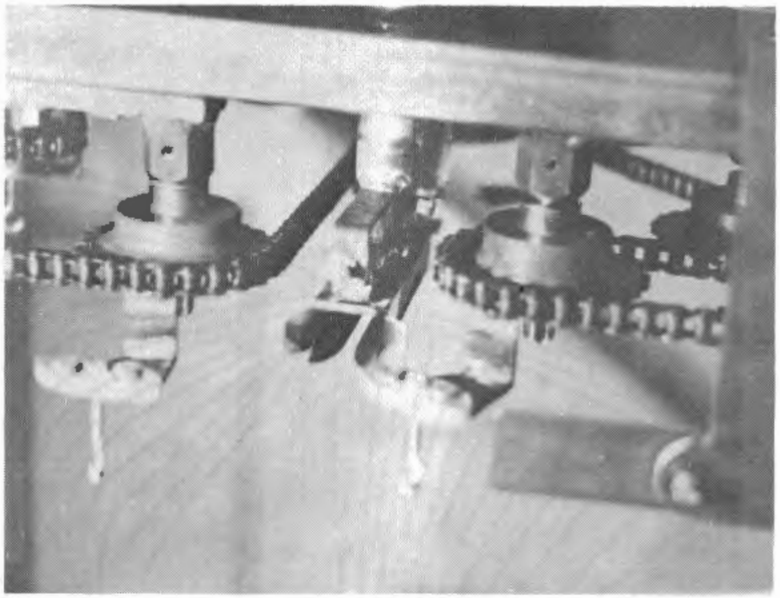


Figure 10. The Hook to Hold the Drying Sample and the Catcher-Weight Holding Unit

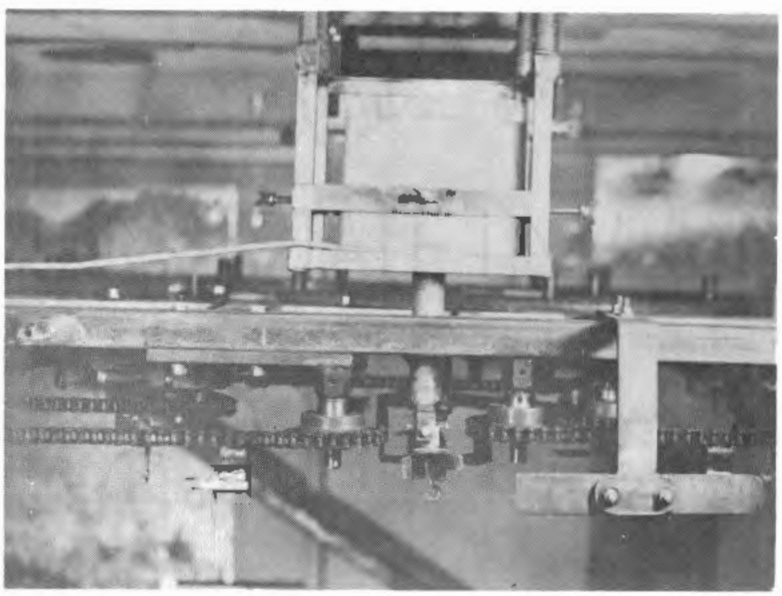


Figure 11. The Catcher-Weight Holding Unit and the Electronic Weighing Sensor

specifically for use with the Hewlitt Packard HP97 programmable printing calculator, served as a data receiver which operated directly from up to six full digits of parallel Binary Coded Decimal (BCD) output of the balance (Figure 12). Data may be entered by use of the "enter" button on the Scientech calculator interface. Remote data entry is done by a remote switch which is operated mechanically by a small lever welded to one of the sprockets (Figure 13). The lever pushes the remote microswitch after the hay samples have transferred to the catcher; at this time the HP97 calculator prints the sample weight and a sample identification. The carrier then proceeds to pick the hook and the hay sample back up. The sample continues to rotate for another half hour before it is weighed again.

Durability Test Device

The durability test device consisted of a hay baler pickup unit and a belt conveyor. The unit was mounted on a frame with adjustable height with respect to the belt conveyor (Figure 14). A variable speed system was used to drive the baler pickup cylinder. A 20-centimeter-wide conveyor belt, running at constant speed of 2.2 meters per second was used to carry the hay batting samples to the pickup unit. A 20-centimeter-wide, Astro-turf sheet was glued to the belt surface to simulate the field condition. In order to control the belt and pickup cylinder speeds independently of each other, a different electric motor was used to drive the conveyor belt. The peripheral speed of the pickup cylinder was slightly faster than the conveyor belt speed. A floating cross-conveyor auger served to move the hay from the pickup unit into a box. That portion of the sample which was not picked up from the belt by the pickup

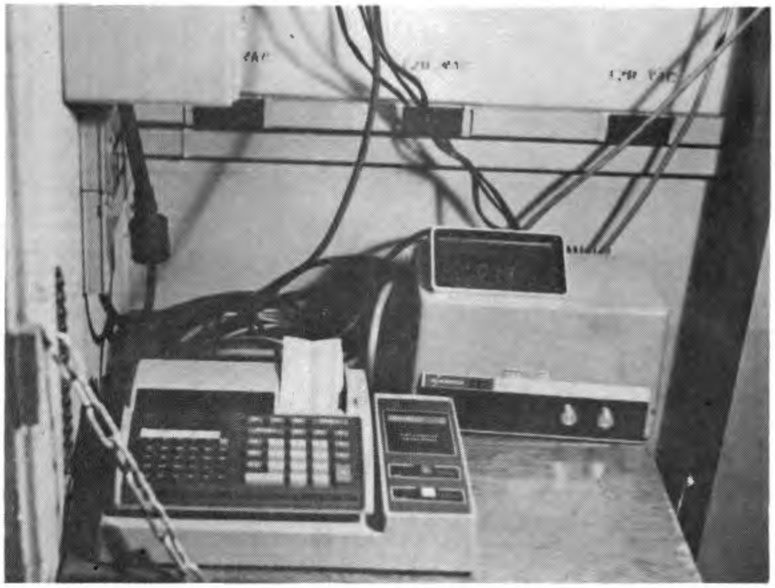


Figure 12. The Weight Recording System

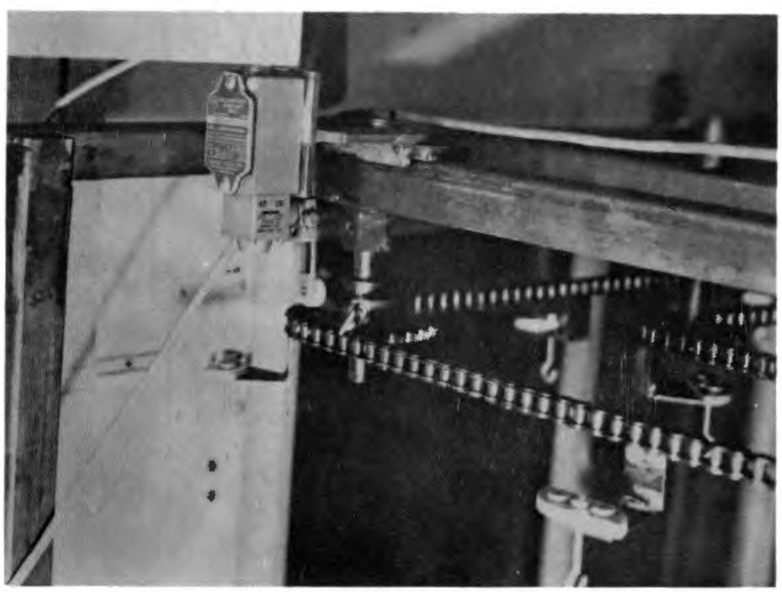


Figure 13. The Remote Control Micro-Switch and Cam Lever on the Sprocket Used to Actuate Weight Recording System

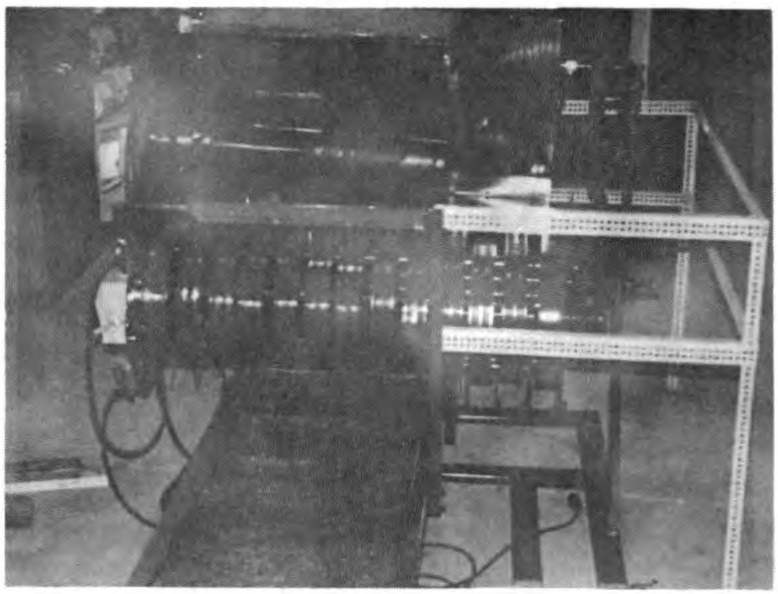


Figure 14. The Batting Durability Test Device Consisting of Pickup Unit of Hay Baler

unit was collected in a tray, weighed, and the losses were recorded. Batt durability was related to these losses.

Other Equipment and Facilities

Two single pan balances were used for weight measurements. One of these had a sensitivity of 0.01 gram and it was used for checking the sample weights for all moisture content determination tests. The other balance with sensitivity of 2.0 grams was used to weigh the amount of freshly cut hay to be run through the conditioning system.

Three drying ovens with heater controls for maintaining a set temperature were used for determining moisture content of all the experimental samples. The control of the oven was set to maintain a temperature of 103 ±2°C for moisture content determinations.

After running the hay sample through the conditioning system, a nylon net cloth with two spring clips was used for wrapping each sample. The nylon nets and clamps were carefully prepared to have equal weights. Aluminum pans, 30.0 cm x 14.3 cm x 8.3 cm, were used for the "bone" dry processing of each sample.

About 200 trays were used to catch the hay batting samples for durability tests. The tray was made of a 90.0 cm x 50.0 cm x 2.5 cm wooden frame and the bottom screen was made from nylon mosquito netting (Figure 15).

Experimental Plan and Procedures

Plan of Experiments

The experiments were conducted in three groups in the following sequences:

Figure 15. Hay Batting Samples in Controlled Environment Laboratory Room

1. Drying rate tests

   a. Determination of drying rate of alfalfa for four levels of roll pressure (0, 12, 14, and 16 kg per cm of roll length) at constant temperature of 35°C and constant humidity of 30 percent. No binders were used in these tests.

   b. Determination of drying rate of hay batting for three levels of crushing roll pressure, first set of rolls (12, 14, and 16 kg per cm of roll length), two binders with three levels of each binder (4, 6, and 8 percent), and two levels of batting roll pressure, second set of rolls (3.5 and 5.0 kg per cm of roll length). The drying conditions were the same as mentioned in 1.a above.

2. Clipping losses test: Determination of amounts of crop losses affected by crushing roll pressure. Four levels of pressure, as mentioned in part 1.a above were used (no binder).

3. Durability test: Determination of durability of hay batting affected by crushing roll pressure, binder type, and batting roll pressure. Three levels of crushing roll pressure, two binders with three levels of each binder, and two levels of batting roll pressure, as mentioned in part 1.b above, were used.

The experiments were conducted in a randomized complete block design with five replications.

For a typical day's run, the drying chamber air temperature and relative humidity was checked. The weighing and recording system was calibrated by hanging known weights on the carriers, running the system, and recording the results. The HP97 calculator was programmed to subtract the weights of net cloth, spring clips and hook from the total weight and therefore to record only the net weight of the hay sample and its identification.

The randomization for each day was provided to every one of the working team. Labels for identification of samples also were provided. A plot of alfalfa was mowed in the morning after the dew had evaporated. The harvested alfalfa was placed into a box and covered by plastic to prevent moisture losses during handling from field to laboratory. Measurements were made for the proper conveyor feed rate, and the same sample weights of the crop were used for all treatments.

Drying Rate of Crushed Alfalfa

According to the randomization, the forage conditioning system adjustments for each specific treatment were made. Freshly cut alfalfa was spread over the charging belt at a density to simulate 2800 kg of dry matter per hectare. This represents an average yield for Oklahoma (Caddel and Taliaferre, 1979). This also would represent a feed rate condition for a windrower having conditioning rolls that would extend full width of the cutter bar. The conveying speed would be equivalent to a forward speed of 8 km per hour for the windrower. All treatments received this same weight and feed rate to provide a standardized basis of comparison for all treatments. The weight of material used, based on an assumed moisture content of the forage of 80 percent (wet basis), was 600 grams per treatment. The arrangement of hay on the charging belt was such that the alfalfa plants were fed with the stem end first and perpendicular to the roll's axis. The treated hay was stopped on the first catching belt and a sample of 150 grams was taken for a drying test. The sample was encased in a nylon net cloth, the end clamped with spring clips and placed temporarily under a plastic cover to reduce moisture losses until four treatments had been collected. All samples were then moved to drying chambers and hung from the hooks which were placed on the carriers (Figure 16). The chain conveyor was turned on and weight recording was done as samples were placed in the drying chamber to determine the samples' initial weight as soon as possible.

Drying conditions were kept the same for all treatments so that the relative response and the drying rate could be determined for each level of treatment. Conditions in the drying chamber were maintained at a mean dry-bulb of 35°C and relative humidity of 30 percent. These conditions were similar to good field drying weather.

The variable characteristics of the alfalfa could only be controlled within ranges. Each plot of alfalfa was harvested about 30 days prior to the test to provide alfalfa with the same age for each treatment to be run. The plants were chosen from the same plot so that characteristics such as initial moisture content, chemical analysis, and growth progress would be similar. Other parameters such as feed rate, conveyor speed, and drying chamber air velocity were held constant for all treatments.

Every effort was made to distribute the temperature and humidity-controlled air uniformly inside the drying chamber and minimize the temperature gradient. The chain conveyor was running constantly during the test, therefore moving the samples continuously inside the chamber helped to eliminate the effects of a temperature gradient.

The chain conveyor completed a cycle in one-half hour; thus the weight and subsequent change in weight of each sample is recorded automatically with respect to time at 30-minute intervals on the HP97 calculator output.

Figure 16. Treated Samples on Carriers in Drying Chamber

Equilibrium moisture contents of all samples were determined after they attained equilibrium with air inside the drying chamber. Attainment of hygroscopic equilibrium with air inside the chamber was indicated when the samples ceased to change weight. The weighing process in the drying chamber was continued until the next morning. The samples then were removed from the drying chamber and placed into the aluminum pans for subsequent drying to a "bone" dry condition. The accuracy of the weighing and recording system was checked by weighing each sample with a scale sensitive to 0.01 grams. The samples were then transferred to a forced air oven maintained at a temperature level of 103°C. The samples usually reached minimum weight within a 12-hour period, but 22 hours of oven drying time was allowed to all samples before recording the dry weight data.

Drying Rate of Hay Batting

The drying rate for the hay batting samples was determined in a method similar to the one described before for finding the drying rate of crushed alfalfa. The same amounts of alfalfa were spread over the charging belt and according to randomization, the crushing roll pressure, binder type and its level of concentration, and batting roll pressure were checked. The samples were stopped on the first catching belt to apply a measured quantity of binder and to mix conditioned alfalfa with the binder. There was no quantitative measure of the uniformity of this mixture. The material stopped on the second catch belt and a 150 gram sample was taken for a drying test.

The sample was encased in a nylon net cloth and the ends clamped with spring clips, as described earlier. The samples then were transferred to the drying chamber at the beginning of each new cycle of the chain conveyor to record the samples' initial weight as soon as possible. About ten samples were transferred to the drying chamber every 30 minutes. The loss of conditioned air each time the drying chamber was opened for transferring the samples into the chamber was minimized by the attached isolation chamber on the front side of the chamber.

The temperature and relative humidity of air inside the drying chamber were monitored during the experiment.

Thirty-six samples were prepared for the batting drying test every day and they were partially dried in the drying chamber, with weights recorded each one-half hour. These samples then were dried in the air oven, as described earlier, at 100°C for a period of 22 hours.

Clipping Loss Tests

To determine the effects of the degree of crushing of alfalfa as cut (at high moisture) on separation of leaves and small stems, a duplicate sample was caught right after the first set of rolls (crushing rolls). The clipping loss tests were without binders. These samples (about 200 grams) were placed on the screen of the shaker and were shaken to separate all components less than 6 cm in length. These separated components included leaves, petioles, and stem tips, and were considered to be a potential clipping loss. This method was found to give essentially the same fractions as picking out by hand all of the long stems (Bruhn, 1955). The stroke and speed of oscillation were 5 cm and 120 rpm, respectively.

The clipping loss fractions and the remaining treated fractions were then separately oven-dried to determine their bone dry weight, so that in determining the clipping loss, both the clipped fraction and the gross sample would be at the same moisture content at the time of loss determination. The percent of separation and that lost was calculated on the 20 percent moisture content (wet basis). The weight of samples at 20 percent moisture content is equal to 1.25 times the bone dry weight.

Durability Test

The durability of the batt was determined by taking an alfalfa sample (about 300 grams) immediately after the sample for batting drying rate study was collected. The samples were caught on a tray, as described earlier, and transferred to the controlled environment laboratory room and were allowed to establish hygroscopic equilibrium with air at desired temperature and humidity levels (Figure 15). The temperature and relative humidity of the room were set at 26.5°C and 70 percent, respectively. Under this condition, using the following equation by Henderson and Perry (1960);

$$1 - rh = EXP\ (-cTM_e^n)$$

the equilibrium moisture content of the samples (M_e) would be 25 percent dry basis (20 percent wet basis). In this equation, rh is relative humidity of the air inside the room; T is the temperature in °R; c and n are material constant having values of $c = 0.351 \times 10^{-4}$; and $n = 1.013$ for alfalfa (Hill et al., 1977).

For the durability test, the samples were weighed and then placed on the batting test device conveyor to carry them to the pickup cylinder. That portion of the sample which was not picked up from the belt by the pickup unit was caught in a metal tray and was considered as the amount lost.

The durability of batting was defined as:

$$\text{Durability} = \frac{W_b - W_\ell}{W_b} \times 100$$

where W_b is weight of sample at 20 percent moisture content (wet basis); and W_ℓ is weight of lost material or the portion of the hay which is not picked up by the pickup unit.

CHAPTER IV

RESULTS AND DISCUSSION

Drying Rate of Crushed Alfalfa (Without Binder)

The drying curves of crushed alfalfa at different levels of crushing roll pressure are shown in Figure 17. It is apparent from these curves that hard crushing significantly speeds the movement of water from alfalfa. This could be the result of crushing the stem in such a way as to split it longitudinally. Thus, more of the stem is exposed to drying and the distance through which the moisture must diffuse is reduced due to splitting of the stem. For all the cases treated or untreated, in the first region of curves, high rates of evaporation of water was noted. About half of the water in the alfalfa was removed in this region for crushed samples. For the drying condition prevailing in this work, the duration of this region was typically two hours for the crushed samples. For the non-crushed samples, the first drying region was influenced mostly by the stomatal opening where water was quite free to evaporate. After this period, the drying rate decreased considerably and stayed nearly constant until equilibrium with the surrounding air was obtained. This part of the drying curves was essentially a diffusion process. After about eight hours, the drying rate for the untreated samples decreased even more. This region of slower drying was probably the result of the water being tightly bound and would require extra energy above the normal diffusion process to remove it.

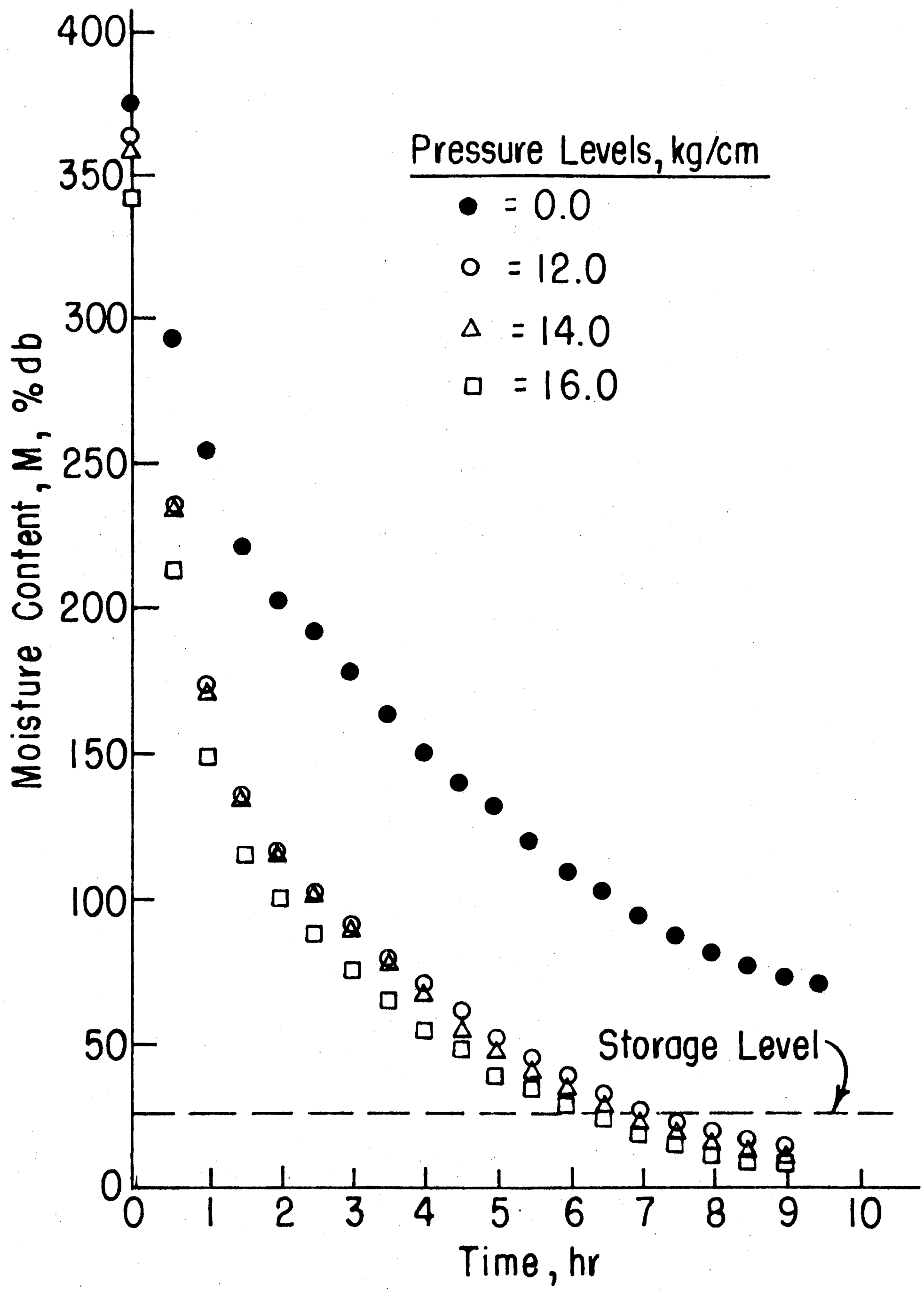


Figure 17. Drying Curves for Alfalfa at Different Levels of Crushing Roll Pressure (No Binder Used)

The degree of crushing influenced the drying time. Figure 18 shows the time required for different levels of crushing roll pressure to cause hay to reach a 25 percent moisture content dry basis (20 percent wet basis) which was considered as a safe storage moisture level.

The results indicated that with hard crushing it would be possible to dry the hay to a storable moisture content within the same day as the hay was cut. This moisture level was reached after 6.2 hours of drying for the hardest crushed samples, and after 6.7 hours and 7.0 hours for second and third levels of crushing roll pressure, respectively. On the average, non-crushed samples did not reach 25 percent moisture content (d.b.) in less than 29.3 hours.

Since hard crushing caused some juice to appear on the alfalfa stem, it had some effect on initial moisture content (Figure 17). To overcome the difficulties of analysis due to varying initial moisture content, a method of comparing the drying rate data from a common initial basis had to be found.

One way of describing a phenomenon depending on various factors was to express the relationship of the factors in a mathematical model. A simple and useful mathematical model describing the drying process of the biological materials may be recalled from the review of literature (Hall, 1957). The model was:

$$MR = EXP\ (-K\theta) \tag{2.2a}$$

where

$$MR = \frac{(M - M_e)}{(M_o - M_e)} \tag{2.2b}$$

The above model reduced the moisture content data, M, to a non-dimensional

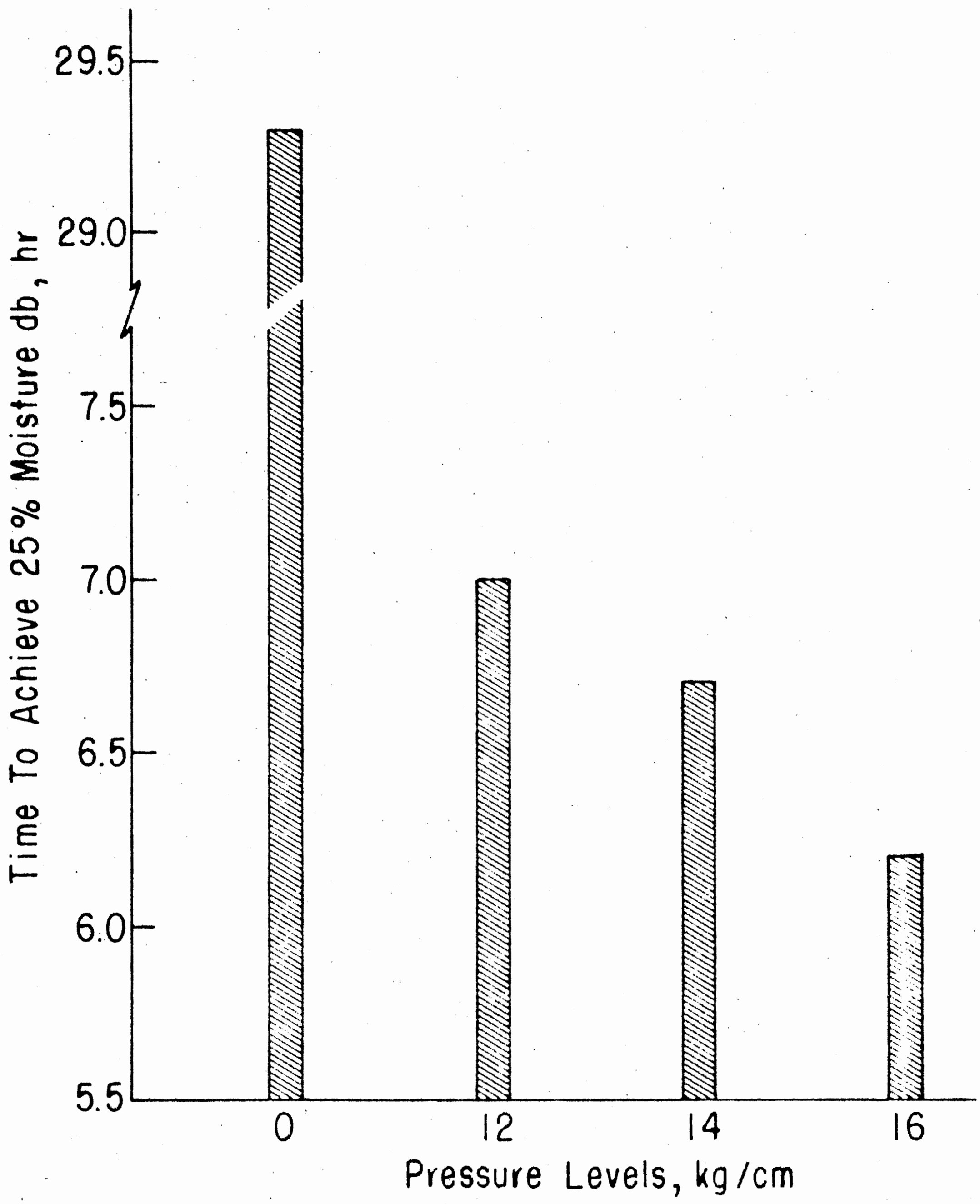


Figure 18. Time Required to Reach 25 Percent Moisture Content (d.b.) Vs. Different Levels of Crushing Roll Pressure; Data Averaged Over Five Replications (No Binder)

moisture ratio, MR, and eliminated the initial moisture, M_o, and the final equilibrium moisture, M_e, in the process. The dependent variable MR was expressed as a function of a single characteristic parameter K and the time θ. The parameter K, called the drying constant or drying index, could describe the rate of moisture removal from alfalfa in terms of the rate of approach towards equilibrium. The data of moisture content shown in Appendix A were successfully fitted to the above model by using a simple transformation for utilizing linear regression techniques, so that:

$$\text{Ln}\ (MR) = -K\theta \qquad (2.2c)$$

The linear regression analysis for fitting the transformed data to the linear model showed a generally high correlation coefficient ($R^2 \geq 0.970$). The null hypothesis of K = 0 could be rejected in each case at a confidence level of 99.9 percent (i.e., $\alpha \leq 0.001$), and the coefficient of variation of the data points were generally in the range of 5 to 20 percent.

After the computation of the value of K for a set of data, the regression line representing the data set was established, and the mathematical model of Equation (2.2c) was then re-transformed to the exponential form of Equation (2.2a). This re-transformation made it possible to plot a prediction line for the moisture content data from the regression coefficient K and from the known values of the initial and equilibrium moisture contents of a particular sample of alfalfa. Figure 19 shows an example of regression line and moisture prediction curve for the drying experiment of alfalfa. The agreement between the moisture content data points and the corresponding points from the fitted curve were similarly close in all cases. The high correlation of the regression lines and

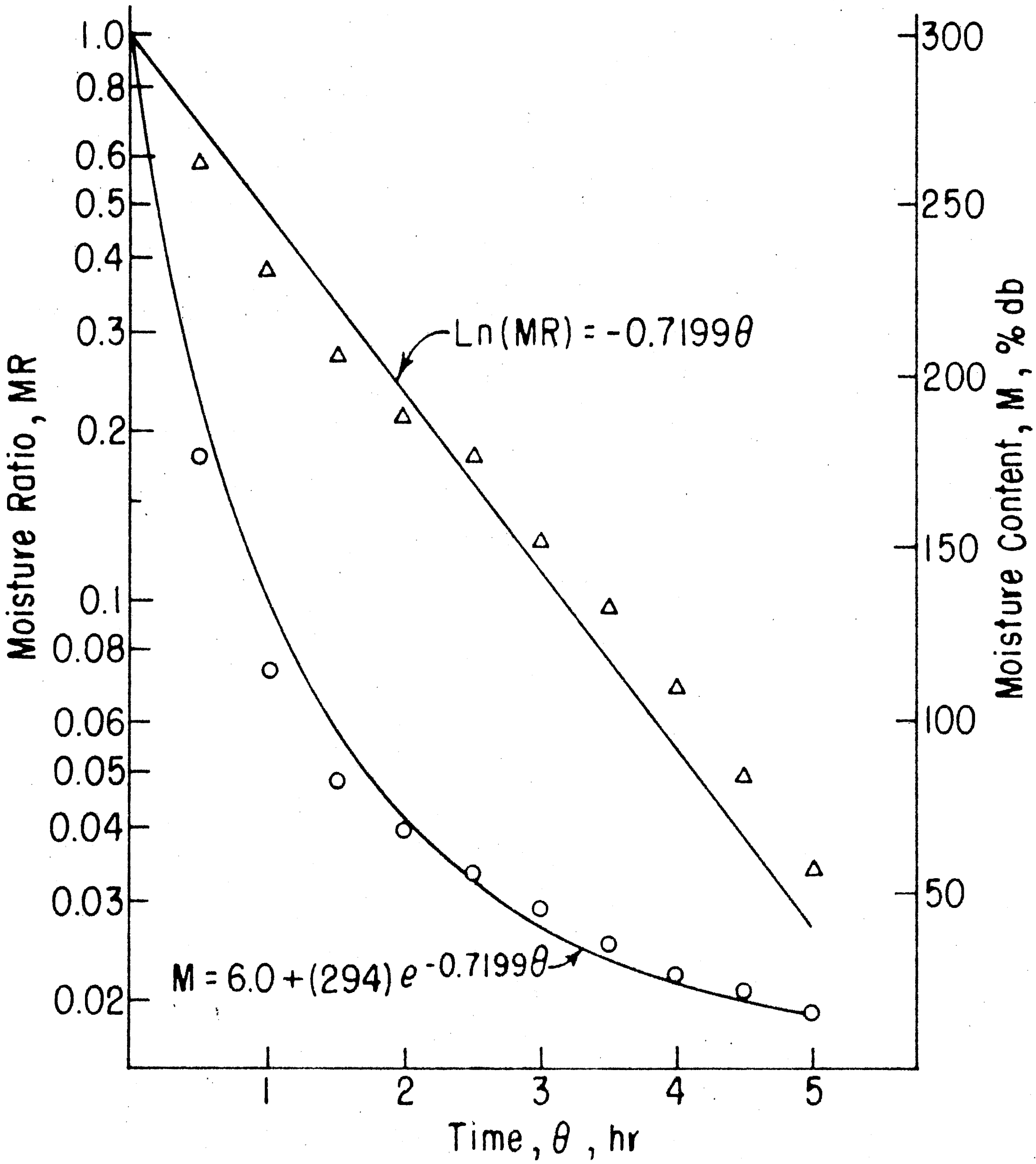


Figure 19. An Example of Drying Regression Line for Drying Constant K, and Prediction Curve for Moisture Content Calculated from K and Other Data (M_o = 300, M_e = 6.0)

the close agreement between the data and the fitted exponential lines were indicative of the appropriateness of the mathematical model chosen for describing the time dependent moisture content value of a thin layer of alfalfa subjected to a constant temperature, relative humidity, and airflow rate.

The values of the drying constant, K, obtained from the crushing experiments of alfalfa are shown in Table II. An analysis of variance was performed on the K values to test the statistical significance of variation due to the different levels of crushing roll pressure. The analysis is shown in Table III. The very high statistical significance of roll pressure on drying rate confirmed, with the known characteristic of alfalfa, that the drying rate is a function of the degree of crushing. Duncan's test was performed to compare each treatment mean with every other treatment mean. The results showed a significant difference between the crushed and uncrushed samples' drying rate. Although there was no significant difference between drying rates of crushed samples at the 95 percent confidence level (i.e., $\alpha = 0.05$), the average values of K shown in Table II indicated that the drying rate was a function of the degree of crushing. The average K values and the corresponding straight lines illustrating the drying model $\text{Ln}\ (MR) = -K\theta$ for this experiment were plotted in Figure 20 to show the effect of roll pressure on drying rate of alfalfa. The lower K values indicated a slower rate of approach towards equilibrium.

The equilibrium moisture contents of the samples were determined after they had attained equilibrium with air inside the drying chamber. Attainment of hygroscopic equilibrium with air inside the chamber was indicated when the samples ceased to change weight. For the non-crushed

TABLE II

EXPERIMENTAL VALUES OF THE DRYING CONSTANT K FOR THE CRUSHED ALFALFA

Crushing Roll Pressure (kg/cm)	Values of K ($hour^{-1}$) for Five Replications*					Average K ($hour^{-1}$)
0.0	0.092	0.111	0.097	0.099	0.100	0.099
12.0	0.585	0.379	0.620	0.395	0.336	0.436
14.0	0.593	0.465	0.421	0.636	0.399	0.502
16.0	0.493	0.566	0.491	0.694	0.480	0.545

*Values of K found from statistical fitting of experimental data to the model $MR = EXP(-K\theta)$.

TABLE III

ANALYSIS OF VARIANCE OF THE DRYING CONSTANT K FOR THE CRUSHED ALFALFA

Source	Degree of Freedom	Sum of Squares	F Ratio	Significance Level*
Corrected Total	19	0.55892		
Crushing Roll Pressure	3	0.41266	15.05	0.0001
Error	16	0.14626		

*Probability of error in rejecting a null hypothesis of significance of the source of variation.

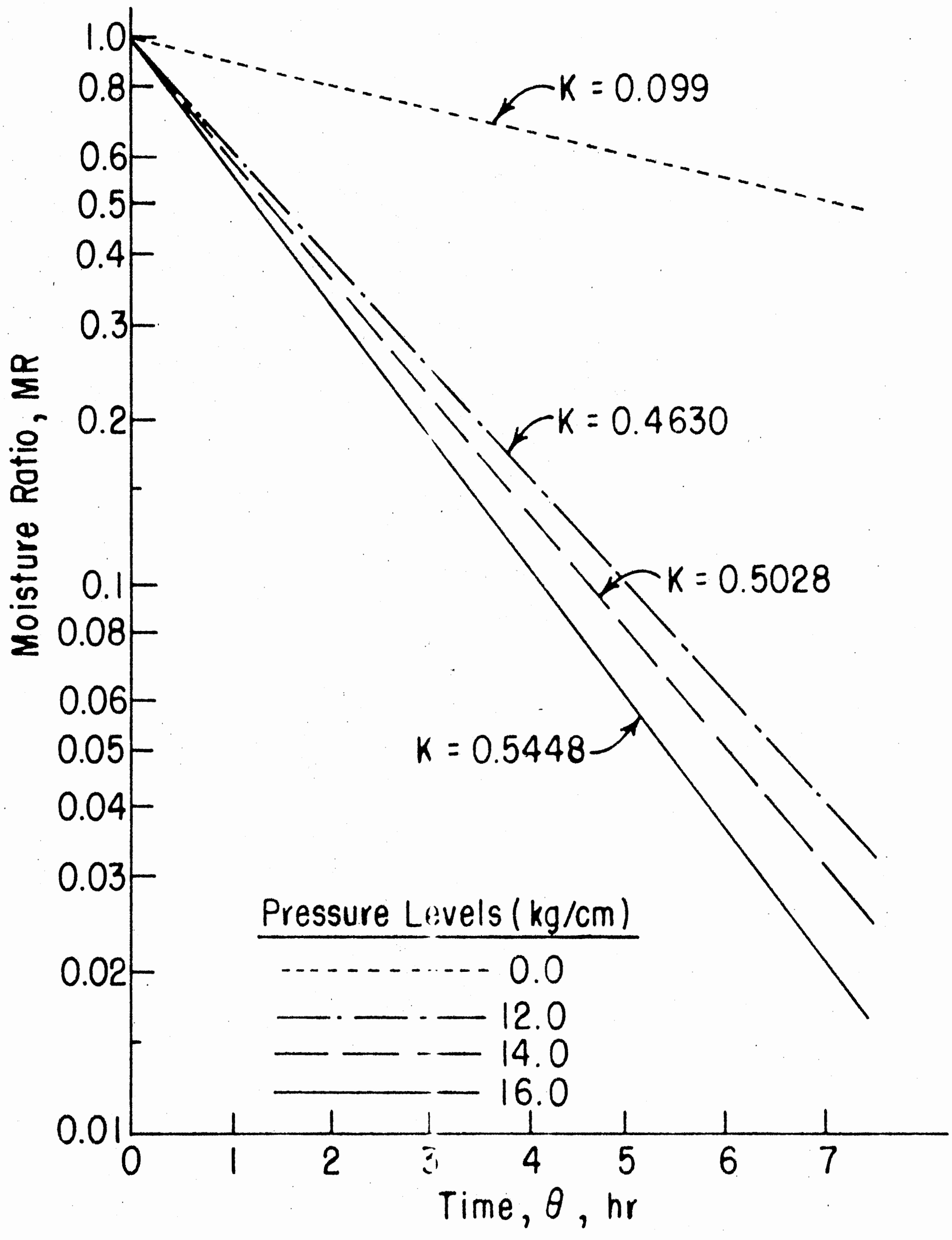


Figure 20. Moisture Ratio Vs. Elapsed Time for Alfalfa at Different Levels of Crushing Roll Pressure (Without Binder)

samples, this did not happen within 24 hours. Therefore, a separate test was conducted to determine the equilibrium moisture content of the untreated alfalfa and these data are included in Table II. For this test the weighing process in the drying chamber continued for 72 hours. The equilibrium moisture was determined and compared with similar work done by Hill et al. (1977). The results showed relatively good agreement between the data found for the two experiments.

Drying Rate of Hay Batting (With Binder)

All K values obtained from this experiment are shown in Table IV and Table XI, Appendix B. The analysis of variance of the values of K for hay batting experiments is shown in Table V. The significances of the crushing roll pressure, batting roll pressure, binder type, and interaction of these three factors were tested. The null hypothesis of no effect could not be rejected for either crushing roll pressure or batting roll pressure. But in the case of the binder alone, the null hypothesis could be rejected at a very high confidence level ($\alpha = 0.0001$). Interactions between the factors were not found significant except for interaction of batting roll pressure and binder, which was found significant at $\alpha = 0.05$.

Since the crushing roll pressure, batting roll pressure, and their interaction were not found significant, averages over all crushing roll pressures and batting roll pressure at each binder level could be computed. The average K values and the corresponding moisture ratio lines are shown in Figure 21. Since the F ratio in Table V was found significant for the binder type factor, Duncan's test was performed to compare each binder level mean with every other binder level mean. The results

TABLE IV

CALCULATED VALUES OF THE DRYING CONSTANT K
FOR HAY BATTING (WITH BINDER)*

Crushing Roll Pressure kg/cm	Batting Roll Pressure kg/cm	Percent Binder Level Used	Average K ($hour^{-1}$)	
			Nutri-Binder	Orzan
12	3.5	4	0.439	0.366
		6	0.365	0.333
		8	0.404	0.319
12	5.0	4	0.563	0.304
		6	0.512	0.350
		8	0.462	0.340
14	3.5	4	0.506	0.344
		6	0.485	0.315
		8	0.484	0.379
14	5.0	4	0.512	0.327
		6	0.483	0.319
		8	0.533	0.346
16	3.5	4	0.465	0.383
		6	0.463	0.323
		8	0.526	0.307
16	5.0	4	0.490	0.318
		6	0.590	0.295
		8	0.447	0.336

*Values of K found from statistical fitting of experimental data to the model $MR = EXP(-K\theta)$.

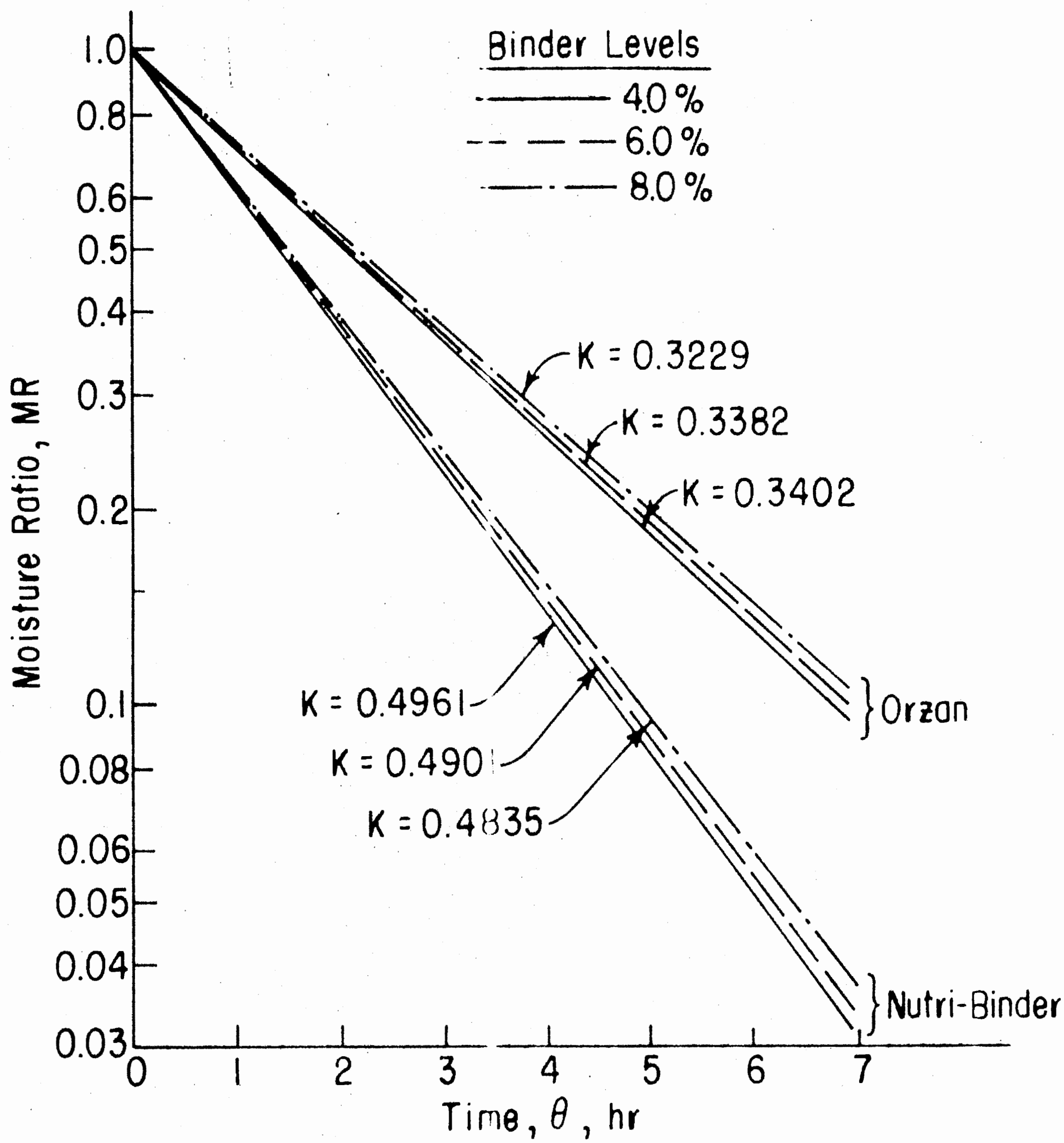


Figure 21. Moisture Ratio Vs. Elapsed Time for Hay Batting Showing K Values Averaged Over Crushing Roll and Batting Roll Pressure Levels

showed a significant difference between Orzan and Nutri-Binder effect on the drying rate of alfalfa. There was no significant difference among the levels of each binder even at the 90 percent confidence level (α = 0.1).

TABLE V

ANALYSIS OF VARIANCE OF THE DRYING CONSTANT K FOR THE HAY BATTING

Source	Degree of Freedom	Sum of Squares	F Ratio	Significance Level*
Corrected Total	179	2.38891		
Crushing Roll Pressure (A)	2	0.00822	0.61	0.5472
Batting Roll Pressure (B)	1	0.00773	1.14	0.2875
Binder Type	5	1.10568	32.58	0.0001
A x B	2	0.13506	1.00	0.3723
A x Binder Type	10	0.05966	0.88	0.5544
B x Binder Type	5	0.09516	2.80	0.0191
A x B x Binder Type	10	0.06976	1.03	0.4232
Block	4	0.07901	2.91	0.0238
Error	140	0.95015		

*Probability of error in rejecting a null hypothesis of significance of the source of variation.

Figure 22 shows the effect of adding a binding agent to hard crushed alfalfa on the drying rate of the crop. The lower K values indicated a slower rate of approach towards equilibrium. The value of K was affected

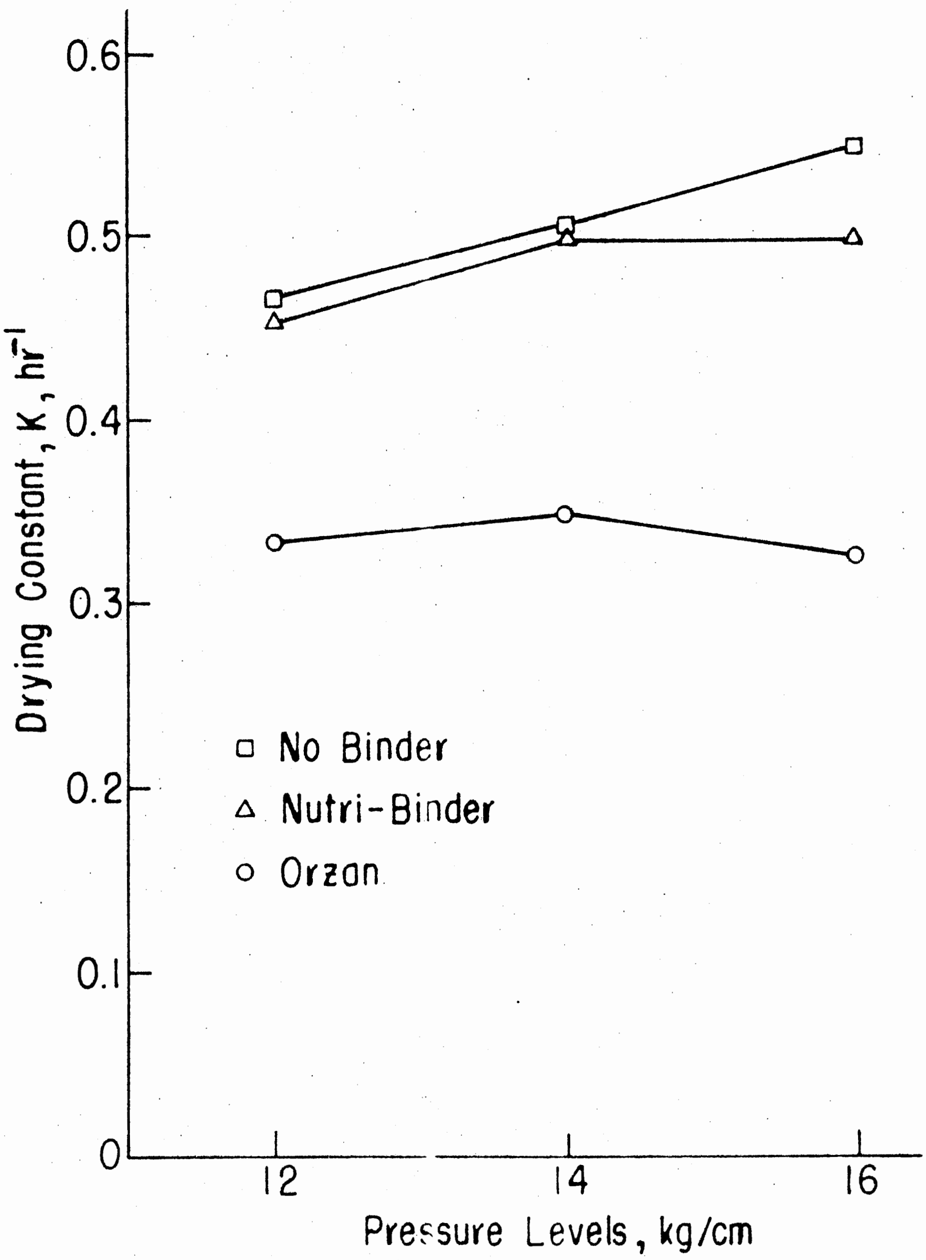


Figure 22. Effect of Crushing Roll Pressure on Drying Constant K for Hay Batting (With Orzan and Nutri-Binder) and Crushed Only Alfalfa; Data Averaged Over Five Replications

by both types of the binding agents. The binders caused a reduction in the value of K, as shown in Figure 22, implying a reduced rate of moisture transfer. The reduction in the values of K for Orzan was more than for Nutri-Binder. The slower drying rate seems to be a result of the adhesion effect due to binding agents which stuck the material together and made it less fluffy. Thus, less air could flow through the hay sample. Orzan had more adhesion effect than did Nutri-Binder, and even with small amounts of juice on the alfalfa stems, caused by hard crushing, it made very strong glue. There was more reduction in the value of K for the hardest crushed samples. This seems to be a result of more juice appearing on the alfalfa, due to hard crushing which absorbed more binder and made for less fluffy material with Orzan. Although the binders caused a reduction in the drying rate, it was apparent from the data in Appendix A that binders also caused a reduction in the initial moisture content of the samples. This reduction for Orzan again was more than that for Nutri-Binder. So, even with a lower value of K, for some combinations of factors, the hay batting (with binder) moisture content reached the storable moisture content in less time than did the crushed (without binder) samples. The reduction in initial moisture content was in direct relation to the percent of binder added to the samples.

The time required for the hay batting to reach 25 percent moisture content (dry basis) for different levels of bonding agents is shown in Figure 23. The graph indicates that samples treated with Nutri-Binder required less drying time than those treated with Orzan. For both agents at the highest level (8 percent), the samples required slightly less drying time than at the 4 and 6 percent levels of binders. However, these differences were not statistically different within a binder type. As

Figure 23. Distribution of Time Required to Approach 25 Percent Moisture Content (d.b.) Vs. Different Levels of Binder for Hay Batting

mentioned earlier, this could be the result of a greater reduction in initial moisture content due to higher amounts of binder. The samples treated at the highest level of Nutri-Binder approached a safe storage level after 6 hours and 15 minutes of drying time, while the samples with Orzan at the same level of binder required 7 hours and 45 minutes. The maximum variation in time to reach 25 percent moisture (d.b.) based upon average values due to the different levels of each binder was about 15 minutes, that is, within a binder type.

The data in Table IV indicated that the maximum value of K (averaged over five replications) was related to samples which were treated at 16 kg/cm crushing roll pressure, 5.0 kg/cm batting roll pressure, and 6 percent of Nutri-Binder. This value of K, as shown in Table IV, was 0.590. Under this condition, the samples reached a safe storage level after 5 hours and 36 minutes.

There was no significant difference between the effect of two levels of the batting roll pressure on the drying rate of hay batting. But values of K averaged over all other factors showed that the drying rate at a higher level of pressure was slightly higher than that at a lower level. This is in agreement with the previous results that drying rate is a function of the degree of crushing.

Potential Clipping Losses (No Binder)

The clipping losses of crushed alfalfa were measured by the shaker system described under research equipment. The separated components were mostly leaves, petioles, and stem tips which may have been caused from excessive crushing pressure.

The clipping loss results are shown in Figure 24. It can be seen

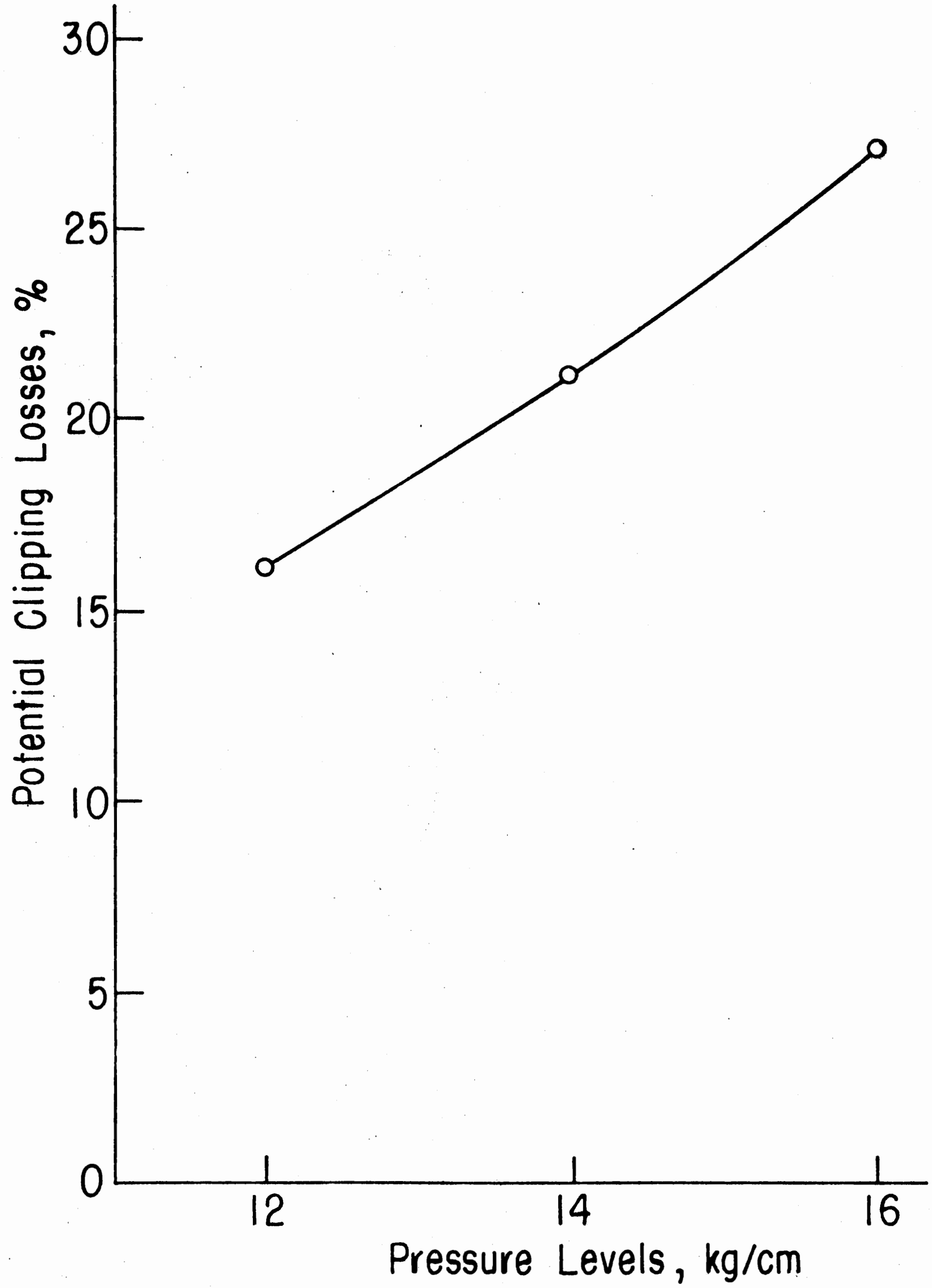


Figure 24. Effect of Degree of Crushing of Alfalfa on Separation of Leaves and Small Stems (Freshly Cut Alfalfa)

from the graph that the percent of separation of leaves and small stems are in direct relation to the degree of crushing. Looking at the data in Table II and Figure 20, it was apparent that the increased drying rate, as well as the increased losses of leaves and small stems were in direct relation to the degree of crushing.

More than 27 percent of the hay was separated by the shaker system as leaves and small stems at the 16 kg/cm roll pressure. It is to be expected that the loss components will include leaves and clipped stems possibly 5 cm in length or less. While not all the components less than 5 cm in length will be lost during the pickup of the cured crop, it is logical to believe that the losses will be essentially in proportion to these components.

Pickup Losses for Crushed Alfalfa (No Binder)

The calculated values of losses from the pickup unit, described under research equipment earlier, for crushed alfalfa are shown in Table VI. It may be recalled from the description of the experimental system that the hay samples contained 25 percent moisture (d.b.) during these evaluations. For these experiments the samples were prepared in the same manner as were the hay batting.

An analysis of variance was performed on the pickup loss data to test for statistical significance of variation due to the different levels of crushing roll pressure. The analysis is shown in Table VII. The very high statistical significance of roll pressure on the pickup losses was in agreement with a previous statement that loss is a function of the degree of crushing. Duncan's test was performed to compare each treatment

TABLE VI

EXPERIMENTAL VALUES OF THE DRY MATTER LOSSES
FOR THE CRUSHED ALFALFA (NO BINDER)

Crushing Roll Pressure (kg/cm)	Values of Dry Matter Losses (%) for Five Replications*					Average (%)
0.0	2.0	2.1	3.0	1.2	1.7	2.0
12.0	14.1	15.5	14.6	15.0	14.3	14.7
14.0	15.6	17.4	19.9	15.8	17.6	17.3
16.0	20.1	20.9	21.3	22.8	21.9	21.4

*Values of dry matter losses found from pickup unit experiment for crushed alfalfa.

TABLE VII

ANALYSIS OF VARIANCE OF THE DRY MATTER LOSSES
FOR THE CRUSHED ALFALFA (NO BINDER)

Source	Degree of Freedom	Sum of Squares	F Ratio	Significance Level*
Corrected Total	19	1068.028		
Crushing Roll Pressure	3	1048.876	292.08	0.0001
Error	16	19.152		

*Probability of error in rejecting a null hypothesis of significance of the source variation.

mean with every other treatment mean. The results showed significant differences between all levels of crushing roll pressure.

The percent of losses averaged over five replications are shown for different levels of roll pressure in Figure 25. For uncrushed samples, 2 percent pickup losses were noted. While it may not happen in actual field operation, it is an interesting point of consideration. The maximum amount of pickup loss was about 21 percent and was associated with the hardest crushed material. This is about 6 percentage points less than that obtained from the clipping loss test which indicated that not all small components of the crushed hay will be lost during pickup of the cured crop. The amount of loss for roll pressures at 12 and 14 kg/cm levels were 14 percent and 17 percent, respectively. These amounts also were considerably less than those obtained from clipping loss tests.

Pickup Losses for Hay Batting (With Binder)

All measured values of pickup losses for the hay batting are shown in Table VIII as percent of original weight. Analyses of variance were performed to test for statistical significance of variation due to different factors involved in making hay batting. The analysis is shown in Table IX. The significance of the crushing roll pressure, batting roll pressure, binder type, and interactions of these three factors were tested. The null hypothesis of no effect could not be rejected for batting roll pressure. But in the case of the binder type, crushing roll pressure, and their interaction, the null hypothesis could be rejected at a very high confidence level ($\alpha < 0.001$). From the data in Table VIII, it was apparent that the batting roll pressure level affected losses in a slightly different magnitude at the different crushing roll pressure

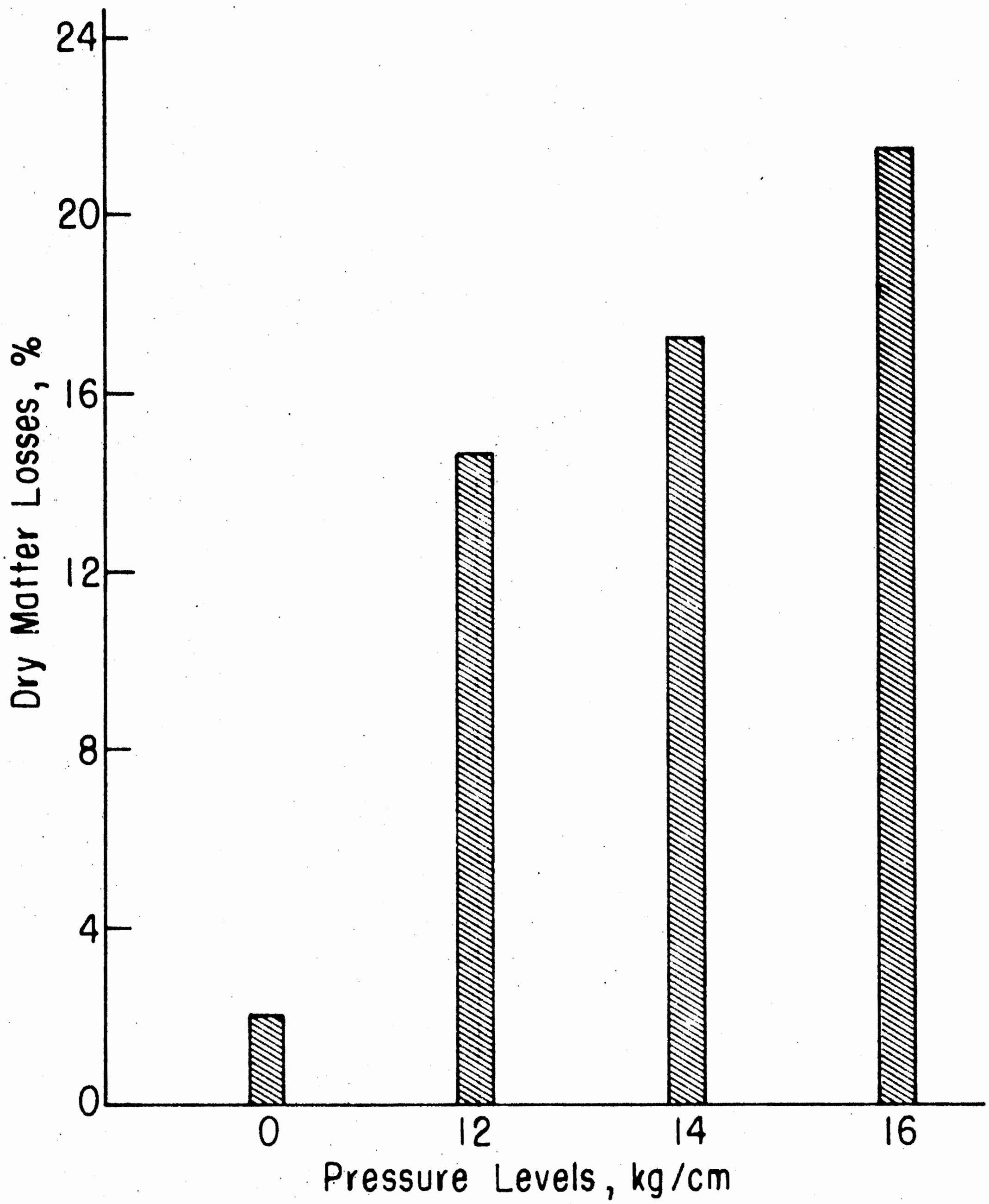


Figure 25. Effect of Degree of Crushing of Alfalfa on Pickup Losses for 25 Percent (d.b.) Hay (No Binder); Data Averaged Over Five Replications

TABLE VIII

DRY MATTER LOSS FOR HAY BATTING (WITH BINDER)*

Crushing Roll Pressure kg/cm	Batting Roll Pressure kg/cm	Percent Binder Level Used	Percent Loss of Dry Matter	
			Nutri-Binder	Orzan
12	3.5	4	8.4	5.2
		6	8.5	4.5
		8	8.3	4.4
12	5.0	4	7.9	5.2
		6	12.8	4.2
		8	7.2	4.9
14	3.5	4	10.3	7.3
		6	9.4	5.0
		8	11.9	4.4
14	5.0	4	11.0	6.1
		6	9.9	5.9
		8	11.4	5.2
16	3.5	4	10.2	7.0
		6	10.8	5.4
		8	11.1	5.5
16	5.0	4	7.2	6.5
		6	9.7	5.6
		8	9.8	5.0

*Values of dry matter losses found from pickup unit experiment for hay batting.

TABLE IX

ANALYSIS OF VARIANCE OF THE DRY MATTER LOSSES FOR THE HAY BATTING (WITH BINDER)

Source	Degree of Freedom	Sum of Squares	F Ratio	Significance Level*
Corrected Total	179	1485.2331		
Crushing Roll Pressure (A)	2	58.9184	12.61	0.0001
Batting Roll Pressure (B)	1	0.4302	0.18	0.6685
Binder Type	5	907.1791	77.67	0.0001
A x B	2	19.5447	4.18	0.0172
A x Binder Type	10	84.4085	3.61	0.0003
B x Binder Type	5	29.8704	2.56	0.0299
A x B x Binder Type	10	43.3265	1.85	0.0566
Block	4	14.4981	1.55	0.1907
Error	140	327.0578		

*Probability of error in rejecting a null hypothesis of significance of the source of variation.

levels. The computed significance level of the crushing roll pressure x batting roll pressure interaction (α = 0.017) was lower than the significance level of the crushing roll pressure factor alone (α = 0.0001), and the apparent interaction might be due to the random error occurring during the experiments.

Since the F ratio in Table IX was found to be significant for the crushing roll pressure factor, a Duncan's test was performed to compare each pressure level mean with every other pressure mean. The results showed no significant difference between the effect of crushing at 14 kg/cm and 16 kg/cm on the amount of dry matter losses. But the effect of crushing at 12 kg/cm resulted in significantly lower losses than that of the two other crushing levels. Figure 26 shows the effect of degree of crushing on the amounts of the pickup dry matter losses for crushed-only alfalfa and also hay batting with binder. It is apparent from Figure 26 that adding a bonding agent to crushed alfalfa reduced the pickup losses. For the hardest crushed samples (16 kg/cm), the amount of the dry matter loss was about 14 percent points less for the hay batting with binder. The reductions for other levels of crushing roll pressure were about 8.0 and 9.5 percentage points per 12 kg/cm and 14 kg/cm roll pressure, respectively.

Hard crushing caused plant juice to appear on the alfalfa stems and this activated the Nutri-Binder and Orzan binder to make a strong glue. The binder, in combination with batting roll pressure, bonded all components of the treated crop together, that is, the separated leaves and small stems were stuck to the main alfalfa stem. That portion of the crop which was not picked up by the pickup test unit was collected and analyzed to determine the fraction of leaves and other separated

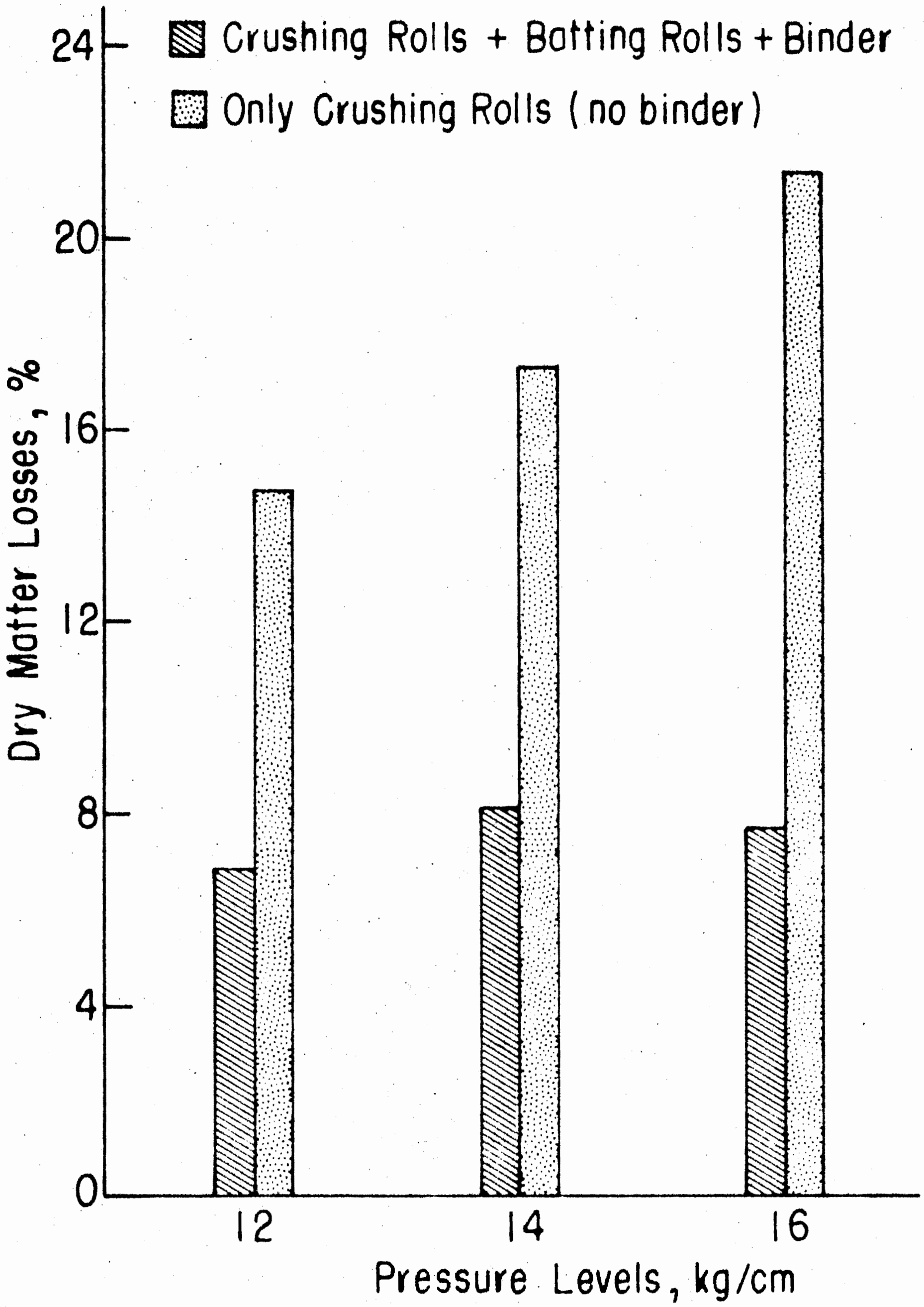


Figure 26. Effect of Degree of Crushing of Alfalfa on Pickup Losses for Hay Batting and Crushed Only Alfalfa; Data Averaged Over Five Replications

components in the combination. For the hay batting, leaves made a small percentage of the total loss and the separated component included mainly small stems. However, for crushed material without a bonding agent added, by observation it appeared that the leaves made a very high percentage of the total losses (Figure 27).

Batting roll pressure (the second set of rolls) did not have a significant effect on the amount of dry matter loss. However, the mean values of dry matter loss due to batting roll pressure, averaged over all the other factors, showed a trend toward slightly less loss for the higher level of the pressure (5.0 kg/cm). This possibly was a result of better bonding of the material together with higher roll pressure (which tends to make a better hay bat).

The Duncan test was performed to compare the effect of different binders and their different application levels on the amount of pickup losses. For Orzan, the maximum amount of dry matter loss in the pickup test occurred at the 4 percent level. There was a significant difference between the effect of the 4 percent level and the two other levels of Orzan. The minimum loss was related to the 8 percent level of Orzan. However, there was no significant difference between the 6 and 8 percent levels. Figure 28 shows the effect of different levels of the binders on the amount of dry matter loss. It is apparent from Figure 28 that the increased rate of Orzan reduced losses.

There was a significant difference between effect of the Orzan and Nutri-Binder on the amount of crop losses. In all cases, losses with Nutri-Binder were more than that from Orzan. As previously stated, this is due to the better adhesion of the Orzan which made a stronger hay batting than did Nutri-Binder. Figure 28 shows slightly different results

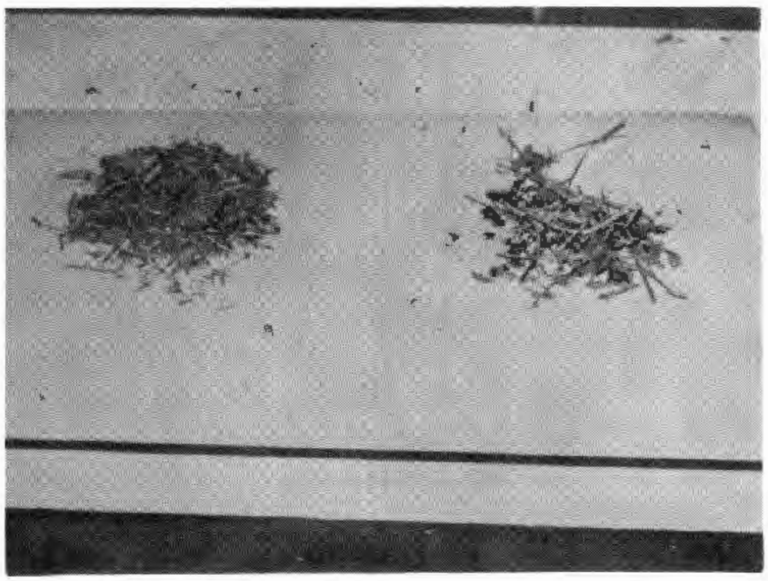


Figure 27. Pickup Losses of Dry Matter for Hay Batting With Binder (Right), and Crushed Only Alfalfa (Left)

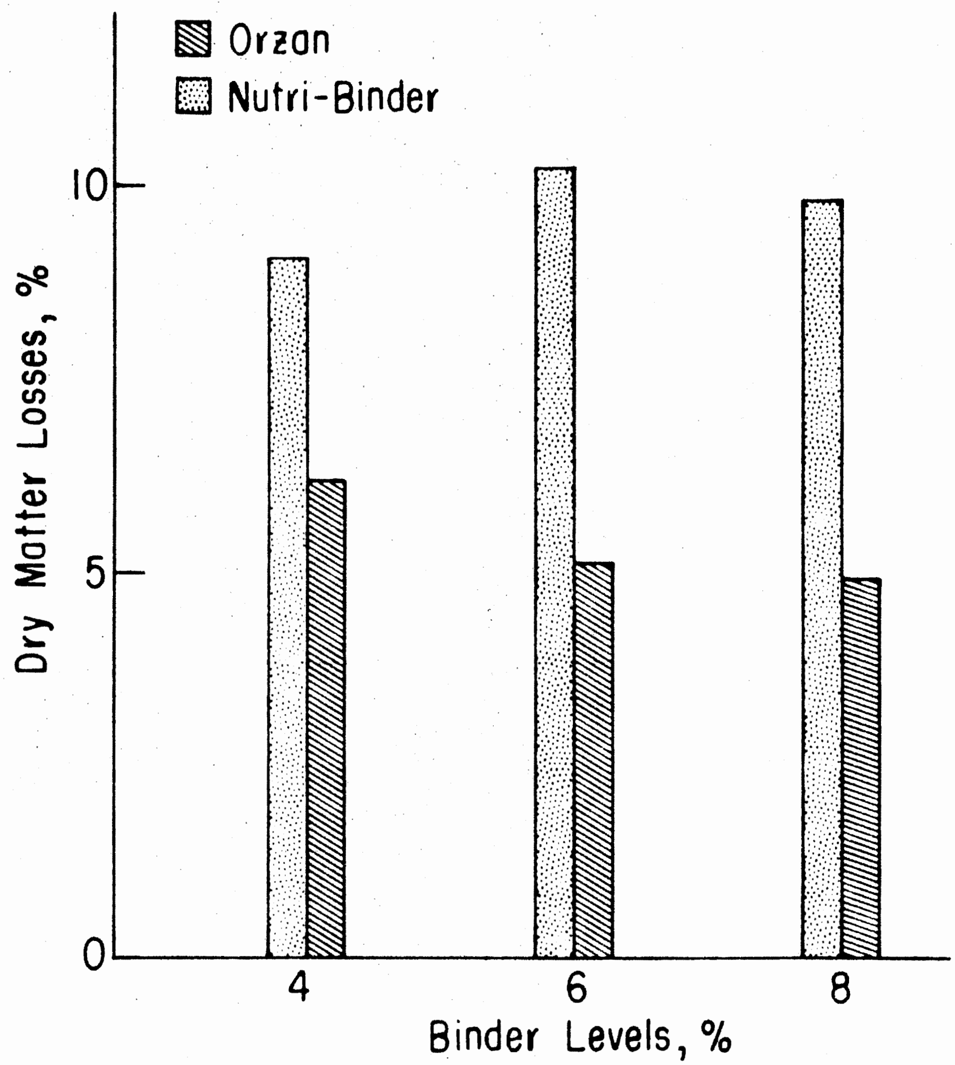


Figure 28. Effect of Levels of Binder on Pickup Losses for Hay Batting; Data Averaged Over Five Replications

for Nutri-Binder as compared to that for Orzan. The minimum loss for Nutri-Binder was related to the samples treated at the 4 percent level of binder. The Duncan test showed a significant difference between the effect of the 4 percent level and the two higher levels of Nutri-Binder. However, there was no significant difference between the effect of 6 and 8 percent levels.

The analysis of losses of dry matter in the pickup test for hay batting with Nutri-Binder showed that losses included some amount of dry binder itself for samples which were treated at higher levels of Nutri-Binder. This increased the amount of losses and could be a result of the poorer adhesion effect of the Nutri-Binder. Orzan apparently was activated with lower amounts of plant juice. The juice caused by hard crushing was not sufficient for the higher amount of Nutri-Binder (more than 4 percent) to make a good bonding. This tends to explain the differences between the results obtained from Nutri-Binder and those obtained from Orzan.

The minimum dry matter loss, averaged over all other factors, was at the 8 percent level of Orzan with a numerical value of 4.9 percent. With a special combination of treatments, even less dry matter loss can be achieved. The data in Table VIII indicated that the minimum value of loss, averaged over five replications, was related to samples which were treated at 12 kg/cm crushing roll pressure, 5.0 kg/cm batting roll pressure, and 6 percent of Orzan. This value of loss, as shown in Table VIII, was 4.2 percent.

Durability of Hay Batting (With Binder)

The durability of each individual hay batting was determined from the previously defined equation:

$$\text{Durability index} = 100\ (W_b - W_\ell)/W_b$$

where

W_b = weight of sample at 20 percent moisture content, wet basis, prior to running it through the pickup unit; and

W_ℓ = weight of lost material (the portion of the hay which was not picked up by the pickup unit).

The durability index was used to determine how well the hay batting would withstand handling. All values of the durability index, averaged over five replications, are shown in Table X for the different treatment combinations. Although the above equation does not establish levels for hay batting quality, a durability index rating of 90 to 95 should be considered "good," and 95 or above "very good."

Figure 29 shows the effect of adding a binder to hard crushed alfalfa on the durability of resultant hay batting. All additives were effective in increasing hay batting durability as compared to no binder. Nutri-Binder had less effect on batting durability than did Orzan. The samples with no binder added did not produce acceptable hay batting durability. The binders caused an increase in the value of the durability index, as shown in Figure 29, implying an increased stability of the hay batting. As previously stated, the increased values of the durability index due to Orzan seems to be a result of the better adhesion effect of this binder which made for a very stable hay batting. Figure 30 shows a hay batting sample made by adding Orzan. In most cases these battings maintained their original form even after passing through the pickup unit.

TABLE X

DURABILITY INDEX OF THE HAY BATTINGS

Crushing Roll Pressure kg/cm	Batting Roll Pressure kg/cm	Percent Binder Level Used	Percent Durability Index	
			Nutri-Binder	Orzan
12	3.5	4	91.6	94.8
		6	91.5	95.5
		8	91.7	95.6
12	5.0	4	92.2	94.8
		6	87.2	95.8
		8	92.8	95.2
14	3.5	4	89.8	92.8
		6	90.7	95.0
		8	88.1	95.6
14	5.0	4	89.0	93.9
		6	90.1	94.1
		8	83.6	94.8
16	3.5	4	89.8	93.1
		6	89.3	94.7
		8	88.9	94.5
16	5.0	4	92.8	93.6
		6	90.4	94.5
		8	90.2	95.0

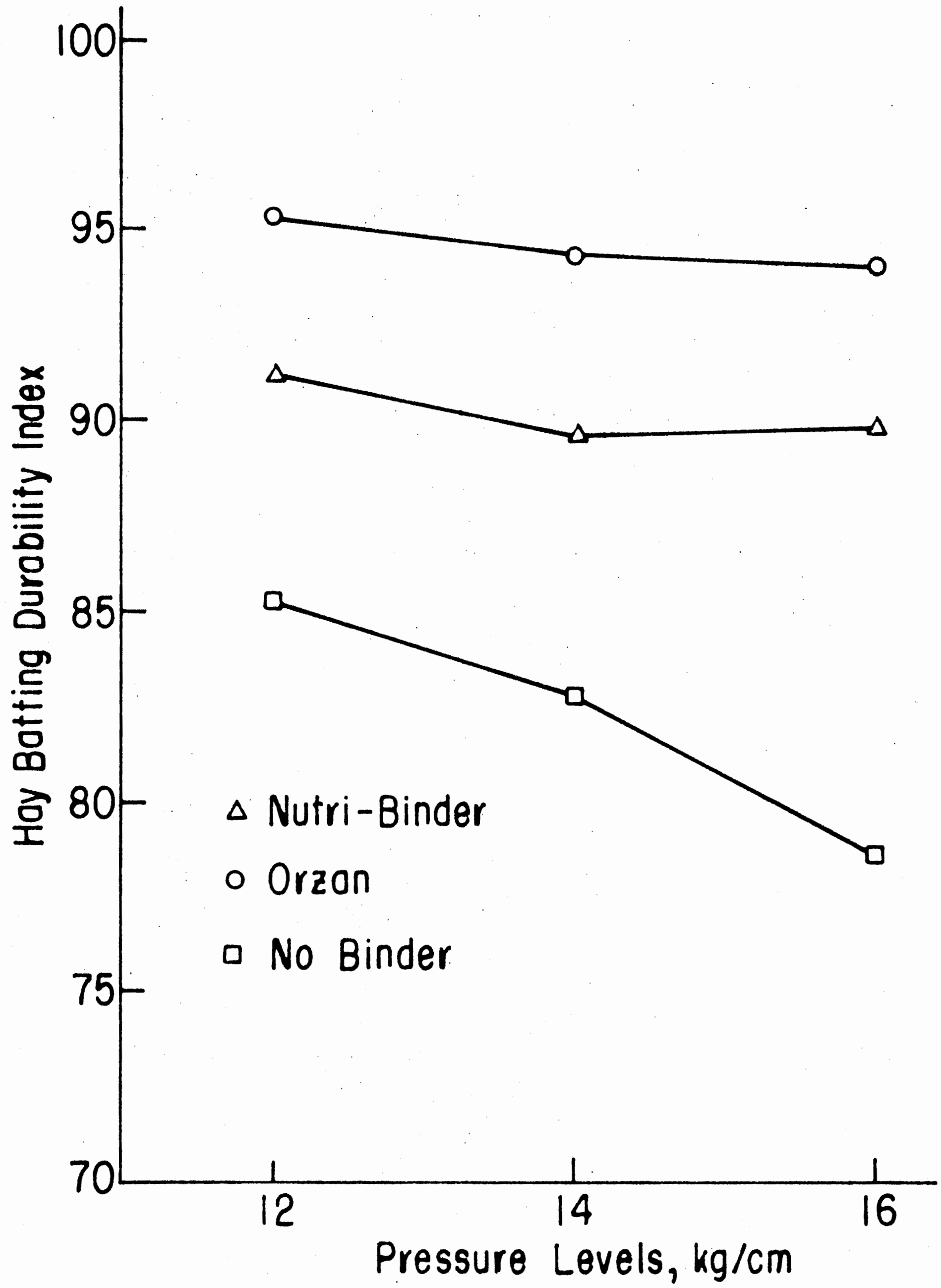


Figure 29. Effect of Crushing Roll Pressure on Durability Index of Hay Batting; Data Averaged Over Other Factors

Figure 30. View of Hay Batting Made of Crushed Alfalfa and Orzan After Durability Tests (Supported Vertically by Hand)

Orzan produced a very good hay batting index of 95 or more percent durability with additive levels of 6 to 8 percent. Figure 31 shows the effect of different levels of binders on the durability of hay batting. For all levels of binder, Orzan had a higher durability than did Nutri-Binder. It is apparent from Figure 31 that the increased rate of Orzan increased the durability of hay batting.

The results for Nutri-Binder were slightly different. Unlike the Orzan, the 4 percent additive level of Nutri-Binder produced a more stable hay batting than did the 6 and 8 percent levels. The Duncan test showed a significant difference between the effect of the 4 percent level and the two higher levels of Nutri-Binder. However, there was no significant difference between effect of the 6 and 8 percent levels. The juice on the alfalfa stem caused by hard crushing was not sufficient to make a good bond at the higher levels of Nutri-Binder. It may be that an excess of Nutri-Binder prevented close contact between the crushed hay particles and thus prevented better bonding for the higher levels of Nutri-Binder.

The most stable hay batting was produced for a combination of treatments of 12 kg/cm crushing roll pressure, 5.0 kg/cm batting roll pressure, and 6 percent of Orzan. This value of the durability index, as shown in Table X, was 95.8 percent.

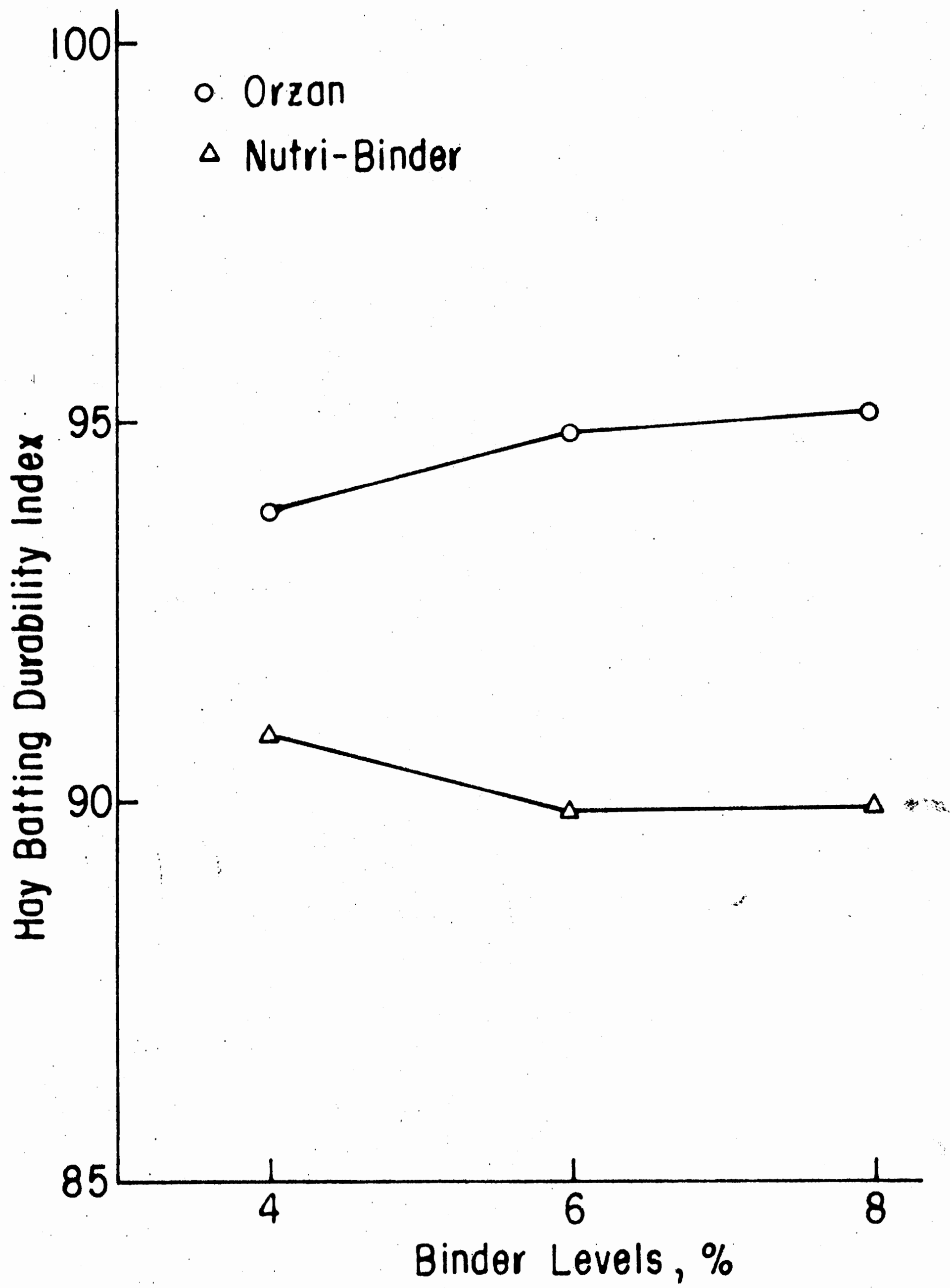


Figure 31. Effect of Different Levels of Binder on Durability Index of Hay Batting; Data Averaged Over Other Factors

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The effects of different degrees of crushing of alfalfa on the drying rate of the crop and the amounts of separation of leaves and small stems were investigated. Four levels of crushing roll pressure (0, 12, 14, and 16 kg/cm) were used (no binders were used in these tests).

In another test, 36 treatment combinations involving three levels of crushing roll pressure, two levels of batting roll pressure, and two binders each at three levels were evaluated as to the effect of these treatments on producing a hay batting. The drying rate of the hay battings and their durability were also investigated. The three crushing roll pressure levels were 12, 14, and 16 kg/cm and two batting roll pressure levels were 3.5 and 5.0 kg/cm. Two types of bonding agents (Nutri-Binder and Orzan) each used at three levels (4, 6, and 8 percent by weight), were also a part of the 36 treatments. The data for the loss of moisture in alfalfa samples while in the drying oven were fitted to an exponential model and drying constants (K) were determined. The data from the pickup losses were used to calculate the hay batting durability index. This index was used to determine how well the hay batting would withstand harvesting.

Conclusions

Hard crushing of alfalfa significantly increased the drying rate of the crop as compared to no crushing (no binder used). There was no statistically significant difference among drying rates of the crushed samples at the $\alpha = 0.1$ level. However, the values of K, averaged over all other factors, indicated that the drying rate was in direct relation to the degree of crushing for these no-binder tests.

The drying rate of hay batting treated with a binder was found to be affected by the type of binder used. An analysis of variance of the computed values of K showed that the differences in binder type was highly significant ($\alpha = 0.0001$). The binders caused a reduction in the value of K, implying a reduced rate of moisture transfer. The reduction in drying rate for Orzan was more than for Nutri-Binder. However, binders also caused a reduction in the initial moisture content of the alfalfa and this was related to the percent of binder added to the samples.

The effects of the crushing roll pressure and batting roll pressure on drying rate were not statistically different for the samples using binder. However, the average values of K indicated that drying rate of alfalfa with binder was a function of the degree of crushing.

The maximum value of K for the hay batting, averaged over five replications, was related to samples treated at 16 kg/cm crushing roll pressure, 5.0 kg/cm batting roll pressure, and 6 percent of Nutri-Binder. Under these conditions, samples reached a safe storage level of 20 percent moisture (wet basis) after 5 hours and 36 minutes of drying time.

The separated components, caused from excessive crushing pressure, were mostly leaves, petioles, and stem tips. Clipping losses were in direct relation to the degree of crushing and the more than 27 percent clipping losses were associated with the highest level of crushing roll pressure.

Pickup losses for crushed alfalfa (no binder) were less than clipping losses (from the freshly cut alfalfa in the shaker test) at all levels of crushing roll pressure. The losses from the pickup test were a function of the degree of crushing. Binders significantly reduced the amount of pickup losses. Orzan was more effective than Nutri-Binder and increased rates of Orzan reduced losses.

Both additives were effective in increasing hay batting durability as compared to no binder. Nutri-Binder had less effect on durability than did Orzan. The samples with no binder added did not produce acceptable hay batting durability. Orzan produced a very good hay batting index of 95 or more percent durability. The increased rate of Orzan increased the durability.

Recommendations for Future Work

The mechanism for mechanically applying the binders to crushed alfalfa should be designed and developed. Orzan GL-50, the liquid form of the Orzan G, could be sprayed directly on a standing plant of alfalfa in the field a few days before harvesting. This method of harvesting should be investigated. However, since Orzan absorbs moisture from the surrounding air very rapidly, the effect of overnight humid air and dew on the performance of this binder should be evaluated.

The nutrient contents of the hay batting after baling should be determined for a better understanding of the effect of binders. Feeding trials with dairy cows or other ruminants should also be considered.

Crushing factors should be found for more levels of roll pressure to compare the effect of hard crushing with those roll pressure which are acceptable in field operation on the drying rate and losses of alfalfa. Since the batting roll pressure was not a significant factor, the drying rate and durability of the hay batting should be evaluated without using the second set rolls, that is, the batting rolls.

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APPENDIX A

CALCULATED MOISTURE CONTENT (WB) FROM ORIGINAL DATA FOR HAY BATTING (WITH BINDER) AND CRUSHED-ONLY ALFALFA

See page 111 for identification of headings.

OBS	PRESA	PRESB	NUTR	ORZ	REP	W0.0	W0.5	W1.0	W1.5	W2.0	W2.5	W3.0	W3.5	W4.0	W4.5
1	12	3.5	0.00	0.04	1	74.8313	66.2443	59.0110	52.4235	49.0437	46.7143	43.4848	40.9810	38.0399	35.0174
2	12	3.5	0.00	0.04	2	70.4912	60.3823	55.2502	50.8621	48.6486	46.4789	43.7731	42.0584	39.9209	37.6197
3	12	3.5	0.00	0.04	3	73.7419	65.4741	58.6281	53.4940	51.8102	50.1292	44.3001	41.0687	37.9421	34.6870
4	12	3.5	0.00	0.04	4	70.1402	60.5472	53.6307	48.9143	46.3385	44.0551	41.7210	39.2663	36.7751	34.3612
5	12	3.5	0.00	0.04	5	70.4670	63.2792	57.7186	53.6638	51.4673	49.1726	46.9790	44.5161	42.0485	39.5218
6	12	3.5	0.00	0.06	1	73.0717	65.2402	58.4551	54.0416	51.2852	47.7690	45.3297	42.8981	40.0602	37.7152
7	12	3.5	0.00	0.06	2	74.0109	64.7874	58.5419	53.3660	50.3906	47.9508	45.0216	42.0091	38.9423	36.2876
8	12	3.5	0.00	0.06	3	72.9181	63.6364	56.6161	51.6324	49.1741	46.6667	44.0559	41.4348	39.0244	36.5079
9	12	3.5	0.00	0.06	4	73.5725	54.8891	49.4475	45.8580	44.0367	42.0886	40.1961	38.3838	36.5318	34.6429
10	12	3.5	0.00	0.06	5	71.8921	59.1503	53.8745	50.0998	48.0249	45.9459	44.0090	41.8605	39.6135	37.2647
11	12	3.5	0.00	0.08	1	70.9656	63.6517	55.0679	50.8009	47.8788	45.2926	42.5901	40.1947	37.4090	34.8485
12	12	3.5	0.00	0.08	2	72.9748	62.1905	54.5767	49.1026	47.3475	44.7844	43.4473	39.9395	37.7743	36.2761
13	12	3.5	0.00	0.08	3	70.9231	59.0830	52.7473	48.3060	46.0661	43.6905	41.4604	39.2811	37.0173	34.7586
14	12	3.5	0.00	0.08	4	72.4765	57.4451	52.0183	48.3202	46.4688	44.4208	42.4642	40.4328	38.3255	36.2972
15	12	3.5	0.00	0.08	5	72.0699	58.2645	52.9357	49.0927	47.0650	38.4896	43.1306	41.0047	38.8620	36.7168
16	12	3.5	0.04	0.00	1	74.2741	66.6375	59.4681	54.8043	51.9546	49.3351	46.6387	43.8881	41.0217	37.9479
17	12	3.5	0.04	0.00	2	78.0371	68.5039	61.9952	55.8011	52.5926	48.9633	45.2991	41.4991	37.6218	33.7474
18	12	3.5	0.04	0.00	3	75.0681	68.5026	62.9555	58.6441	56.2201	53.8462	51.2650	48.6676	45.7778	42.9907
19	12	3.5	0.04	0.00	4	76.3014	69.1071	62.6350	57.5460	54.7712	51.8776	48.9676	45.9375	42.6202	39.4046
20	12	3.5	0.04	0.00	5	78.7449	67.8899	59.4072	53.1947	49.8408	46.3373	42.8312	39.3064	35.8452	32.4034
21	12	3.5	0.06	0.00	1	77.1711	67.9298	62.0350	54.4021	50.5698	47.5038	44.3018	41.8760	39.1228	35.8595
22	12	3.5	0.06	0.00	2	75.8668	67.8442	62.1131	57.4341	53.9559	52.0270	48.9943	46.2121	42.6494	39.5230
23	12	3.5	0.06	0.00	3	72.9152	64.0439	56.8606	51.6605	48.8281	46.2380	43.4532	40.6133	38.0128	35.3618
24	12	3.5	0.06	0.00	4	70.4926	61.2054	55.5015	51.3830	49.1657	46.9838	44.5388	42.1519	39.9474	37.4829
25	12	3.5	0.06	0.00	5	75.0999	67.6471	61.2435	56.5621	54.0541	51.4916	48.9071	46.2644	43.5045	40.7290
26	12	3.5	0.08	0.00	1	76.7206	66.3196	60.5714	55.2529	50.7143	47.3282	44.2649	40.9247	37.8378	33.9080
27	12	3.5	0.08	0.00	2	73.5836	66.0526	60.7107	55.7714	53.1477	50.4481	47.5610	44.7143	40.5530	38.3758
28	12	3.5	0.08	0.00	3	74.8641	66.0862	59.4743	50.7324	47.0672	43.7690	40.5145	36.5676	33.6518	30.3202

OBS	PRESA	PRESB	NUTR	CHZ	REP	W5.0	W5.5	W6.0	W6.5	W7.0	W7.5	W8.0	W8.5	W9.0	Wo
1	12	3.5	0.00	0.04	1	32.1616	29.3561	26.7191	23.5656	21.3080	18.3807	15.6109	13.4571	10.9785	7.90123
2	12	3.5	0.00	0.04	2	35.3191	32.9412	30.4878	27.8481	25.4902	22.8426	19.4346	17.5407	15.0838	7.12831
3	12	3.5	0.00	0.04	3	31.6814	28.5165	25.3385	22.3340	19.7505	17.3448	15.3509	13.6465	11.6705	7.87589
4	12	3.5	0.00	0.04	4	32.0659	29.6063	27.5527	25.2508	23.1959	20.8850	18.8748	17.0686	15.0190	7.26141
5	12	3.5	0.00	0.04	5	37.0425	34.3511	31.7460	29.0429	26.2436	23.4875	20.8103	17.9369	15.0198	7.32759
6	12	3.5	0.00	0.06	1	35.0734	32.1976	29.5575	27.1062	24.6212	22.7184	20.5589	18.2752	15.4989	8.08314
7	12	3.5	0.00	0.06	2	33.7391	30.8530	28.1132	25.5859	23.3400	19.9580	17.8879	16.8122	15.3333	8.19277
8	12	3.5	0.00	0.06	3	33.9934	31.5068	29.0780	26.4706	24.3856	22.0273	19.8397	17.6955	15.6118	8.04598
9	12	3.5	0.00	0.06	4	32.6380	30.6818	28.7013	26.8975	24.8974	23.0014	21.0072	19.1458	17.0695	7.26351
10	12	3.5	0.00	0.06	5	35.0649	32.7052	30.2650	27.8499	25.4844	22.9584	20.5087	18.1669	16.2479	7.40741
11	12	3.5	0.00	0.08	1	32.3699	29.6236	26.4957	24.4288	21.6758	19.6262	17.4664	15.3543	13.3065	7.52688
12	12	3.5	0.00	0.08	2	34.2715	32.0205	28.9803	27.8182	25.7944	23.8004	22.0039	18.8139	17.6349	7.67442
13	12	3.5	0.00	0.08	3	32.6211	30.5433	28.5498	26.3240	24.5614	22.5859	20.9030	19.0068	17.1629	7.25490
14	12	3.5	0.00	0.08	4	34.2965	32.0779	29.7987	28.0605	26.1299	23.7509	22.0566	20.0306	18.1534	7.10480
15	12	3.5	0.00	0.08	5	34.6701	32.4866	30.1521	28.0627	25.8443	23.6006	21.2168	19.0705	17.0772	7.33945
16	12	3.5	0.04	0.00	1	34.8718	31.9643	28.7850	26.1628	23.3400	20.4593	17.8879	14.7651	12.6147	7.07317
17	12	3.5	0.04	0.00	2	29.8246	25.7541	20.7921	16.6667	12.8065	10.6145	7.7610	7.2464	6.9767	6.70554
18	12	3.5	0.04	0.00	3	39.7035	37.0052	33.8156	30.8129	27.6680	24.5361	21.2903	18.4855	15.4734	6.87023
19	12	3.5	0.04	0.00	4	36.1624	32.9457	29.9595	26.6949	23.9560	21.0046	18.7793	15.8151	13.7157	7.23861
20	12	3.5	0.04	0.00	5	27.2517	25.5319	22.4138	19.4373	16.6667	14.4022	12.5000	10.7649	8.9595	7.07965
21	12	3.5	0.06	0.00	1	33.5249	30.4609	27.5574	25.0540	22.7171	19.8614	16.5865	14.7420	12.3737	7.21925
22	12	3.5	0.06	0.00	2	36.4937	33.6449	30.3922	27.2541	23.9829	21.1111	18.0139	15.8768	13.2029	7.06806
23	12	3.5	0.06	0.00	3	32.7055	30.1954	27.6243	25.0000	22.6378	20.4453	17.9541	15.8458	13.8158	7.09220
24	12	3.5	0.06	0.00	4	34.9929	32.2963	29.8003	27.3450	24.8355	22.2789	19.9650	17.3599	15.0558	7.11382
25	12	3.5	0.06	0.00	5	38.3855	35.5172	32.9749	30.4833	27.9383	25.7937	23.3607	21.2632	19.0476	7.42574
26	12	3.5	0.06	0.00	1	30.8617	28.5714	25.4860	22.1219	19.2037	17.2662	14.6040	12.6582	10.3896	7.75401
27	12	3.5	0.06	0.00	2	35.0671	31.7460	28.4658	25.0000	21.8182	18.6975	15.8696	12.6411	10.2088	7.19424
28	12	3.5	0.06	0.00	3	23.3954	24.1803	21.7759	19.0372	16.8539	14.7465	12.7358	11.2710	9.7561	7.73067

OBS	FRESA	PRESH	NUTR	ORZ	REP	W0.0	W0.5	W1.0	W1.5	W2.0	W2.5	W3.0	W3.5	W4.0	W4.5
29	12	3.5	0.06	0.00	4	72.3622	63.1913	55.4825	49.8146	46.8586	43.7673	40.6433	37.5385	34.6216	31.3029
30	12	3.5	0.06	0.00	5	75.4808	66.6667	58.6327	52.1448	48.6331	44.9074	40.8940	36.4769	32.2581	27.8788
31	12	5.0	0.00	0.04	1	73.9365	67.1489	61.4386	57.3481	55.2723	53.2121	49.7396	47.4830	45.0925	42.7300
32	12	5.0	0.00	0.04	2	72.6215	65.0044	60.0400	55.8011	53.6501	51.5152	49.4311	47.0899	44.2857	42.6112
33	12	5.0	0.00	0.04	3	73.8801	67.0721	61.2078	56.7352	54.4471	52.0860	49.4667	46.7697	44.0177	41.2403
34	12	5.0	0.00	0.04	4	72.3477	65.4405	59.9604	55.8470	53.7228	51.5588	49.2462	46.5120	44.5055	42.0373
35	12	5.0	0.00	0.04	5	71.5647	58.8235	53.1996	49.3802	47.4812	45.5556	43.5484	41.4576	39.3564	37.3402
36	12	5.0	0.00	0.06	1	73.0717	65.2402	59.4705	55.8758	53.6131	51.1057	46.7202	44.2577	41.8129	39.2366
37	12	5.0	0.00	0.06	2	72.2638	62.9764	57.1878	52.4476	49.8771	47.3548	44.7903	42.4542	39.6450	37.3272
38	12	5.0	0.00	0.06	3	73.2835	64.6583	57.6052	52.4213	49.6799	47.0350	44.0967	41.2556	38.3046	35.4680
39	12	5.0	0.00	0.06	4	70.4698	60.8096	54.6361	50.2732	48.1777	45.8333	43.5484	41.0622	38.8441	36.2745
40	12	5.0	0.00	0.06	5	73.2057	65.7343	59.4623	54.7866	52.3114	49.8079	47.2409	44.7887	41.9259	39.1304
41	12	5.0	0.00	0.08	1	70.7944	58.4079	49.5662	43.4307	40.6888	38.2470	35.7735	32.8035	30.5970	28.6591
42	12	5.0	0.00	0.08	2	71.6291	57.8858	52.4095	49.1770	46.9957	45.2328	42.5581	39.9027	39.7561	37.6616
43	12	5.0	0.00	0.08	3	72.2034	63.8448	57.2917	52.5463	50.0609	47.5032	45.0402	42.1721	39.7944	37.0200
44	12	5.0	0.00	0.08	4	72.1167	63.9157	57.5851	53.0286	50.4819	47.9087	45.2730	43.3884	39.6476	37.0597
45	12	5.0	0.00	0.08	5	70.3880	62.4352	57.0158	53.2258	51.2878	49.3007	47.2027	45.3518	43.0628	40.9769
46	12	5.0	0.04	0.00	1	74.6640	67.1603	61.2539	55.3318	52.2180	49.1228	47.6389	44.9635	42.0000	39.7764
47	12	5.0	0.04	0.00	2	74.2566	65.2372	57.9006	51.7110	46.4135	44.7025	41.3646	32.2064	41.9207	28.5178
48	12	5.0	0.04	0.00	3	75.9373	64.1988	53.3686	44.9298	40.2707	35.9347	31.3230	27.3663	23.4273	19.5900
49	12	5.0	0.04	0.00	4	74.4753	65.1571	57.2562	51.2290	47.9282	44.3953	40.3481	36.6387	32.6786	29.1353
50	12	5.0	0.04	0.00	5	76.7601	68.1051	60.1407	53.7415	50.1466	46.3722	42.1769	37.5562	33.5937	29.1667
51	12	5.0	0.06	0.00	1	74.0716	63.5328	53.3981	46.1431	42.2556	37.5610	33.6788	30.8108	27.6836	24.7059
52	12	5.0	0.06	0.00	2	75.1026	67.5868	62.3188	57.5263	55.2826	52.6658	50.1370	46.7057	42.9467	41.5730
53	12	5.0	0.06	0.00	3	74.8428	62.3431	50.1385	39.7993	34.1865	29.8246	25.0000	20.7048	17.2414	14.0811
54	12	5.0	0.06	0.00	4	70.3768	62.3032	56.8720	51.8008	50.5972	48.5294	46.1538	43.7577	41.5167	39.0080
55	12	5.0	0.06	0.00	5	75.3086	63.7462	54.0816	46.9809	43.1280	39.4958	35.8289	32.2034	28.8538	25.6198
56	12	5.0	0.06	0.00	1	71.5733	63.1349	54.4372	48.7211	45.0392	40.2837	39.5983	36.4048	33.1746	29.9501

CPS	FRESA	PRESB	NUTR	ORZ	REP	W5.0	W5.5	W6.0	W6.5	W7.0	W7.5	W8.0	W8.5	W9.0	We
29	12	3.5	0.06	0.00	4	23.2686	25.2302	22.6667	20.2358	17.9798	15.7676	13.9631	11.9306	10.1770	7.72727
30	12	3.5	0.06	0.00	5	23.8806	19.7753	16.3934	13.3495	10.5263	8.2262	7.9897	7.7519	7.5130	7.03125
31	12	5.0	0.00	0.04	1	40.2477	37.8422	34.9073	32.3993	29.8182	27.1698	25.4826	22.8000	19.9170	7.21154
32	12	5.0	0.00	0.04	2	40.2093	37.8882	35.3796	33.2220	30.5556	28.3154	25.6506	23.0769	20.3187	7.19258
33	12	5.0	0.00	0.04	3	38.3740	35.6537	32.5623	30.3309	26.6925	23.8956	21.3693	18.4946	16.3355	7.10784
34	12	5.0	0.00	0.04	4	39.4303	36.6771	34.0946	31.7568	28.9982	26.4117	24.0602	21.7054	19.0381	7.12644
35	12	5.0	0.00	0.04	5	35.2706	33.2425	31.0830	26.9855	26.8657	24.6154	22.5908	20.1954	18.3333	7.19697
36	12	5.0	0.00	0.06	1	36.6242	34.1060	30.9028	28.2883	25.4682	23.3141	21.3439	18.4426	16.0338	7.44186
37	12	5.0	0.00	0.06	2	34.6154	32.1131	29.4118	27.1429	24.3043	21.9885	19.6650	17.2414	14.8225	7.27273
38	12	5.0	0.00	0.06	3	32.4742	29.5699	26.8156	24.4231	21.7131	18.9691	17.0886	14.9351	13.0531	7.31132
39	12	5.0	0.00	0.06	4	33.6735	31.2689	28.7950	26.4943	24.0401	21.9554	19.4690	17.4229	15.1119	7.14286
40	12	5.0	0.00	0.06	5	36.4668	33.6717	31.1072	28.3364	25.4753	22.9862	20.1629	17.9916	15.1515	7.10900
41	12	5.0	0.00	0.08	1	26.4241	24.3902	22.2408	20.1031	18.7063	16.6667	14.3646	12.7580	11.4286	7.00000
42	12	5.0	0.00	0.08	2	35.4248	33.5128	31.5789	28.9209	27.3529	25.2648	23.0530	21.0863	19.1489	7.14286
43	12	5.0	0.00	0.08	3	33.8710	31.3233	28.6957	25.7246	22.9323	19.9219	17.3387	14.2259	11.6379	7.23982
44	12	5.0	0.00	0.08	4	33.8164	31.1558	28.1469	25.6781	22.8893	20.3488	17.8000	15.9509	13.1078	7.43243
45	12	5.0	0.00	0.08	5	38.7324	36.5889	34.2900	32.0312	29.9517	27.6206	25.3859	23.1449	20.9091	7.05128
46	12	5.0	0.04	0.00	1	37.2712	34.3206	31.2044	27.9159	25.6410	22.5873	19.9575	16.4080	14.1230	7.37101
47	12	5.0	0.04	0.00	2	23.4940	21.2810	15.7080	12.0092	9.5012	9.0592	8.6331	8.1928	7.7482	7.29927
48	12	5.0	0.04	0.00	3	16.5485	14.1119	11.3065	9.0206	8.5492	8.0729	7.5916	7.3491	7.1053	6.86016
49	12	5.0	0.04	0.00	4	25.3465	22.4280	18.9247	16.2222	13.7300	11.9159	10.0239	8.9372	7.3710	6.68317
50	12	5.0	0.04	0.00	5	24.7788	20.5607	16.8704	13.4860	11.2272	8.6022	8.1081	7.6087	7.1036	6.84932
51	12	5.0	0.06	0.00	1	21.4724	18.9873	16.3399	13.3183	11.3164	9.6471	7.9137	7.4699	7.0218	6.79612
52	12	5.0	0.06	0.00	2	39.6172	36.0281	31.4501	28.7671	24.1667	21.7204	18.5682	15.1515	12.0773	7.84810
53	12	5.0	0.06	0.00	3	11.5479	9.5477	7.9284	7.4550	6.9767	6.4935	6.2500	6.0052	5.7592	5.51181
54	12	5.0	0.06	0.00	4	36.6295	34.0580	31.4759	29.1277	26.7311	24.2928	21.9554	19.6113	17.4229	6.57084
55	12	5.0	0.06	0.00	5	22.7468	19.8218	17.2414	15.0943	12.8329	11.5479	9.7744	8.6294	7.2165	6.73575
56	12	5.0	0.08	0.00	1	26.6551	22.1811	20.2652	17.4510	14.6045	11.9247	9.0713	7.4725	5.6054	5.18018

OBS	FRESA	PRESB	NUTR	ORZ	REP	W0.0	W0.5	W1.0	W1.5	W2.0	W2.5	W3.0	W3.5	W4.0	W4.5
57	12	5.0	0.08	0.00	2	77.7248	69.1509	62.0209	57.3107	53.6170	51.3393	48.0127	44.9495	41.5027	37.8327
58	12	5.0	0.08	0.00	3	73.8893	65.1460	57.4610	51.4612	48.3784	45.3505	42.1212	38.8800	35.7983	32.7465
59	12	5.0	0.08	0.00	4	73.4375	63.8966	55.4162	48.5526	45.7698	42.4153	39.2857	36.0065	33.0479	29.6763
60	12	5.0	0.08	0.00	5	77.7931	70.1021	62.7746	56.8942	53.5354	50.0000	46.2437	42.3971	38.4321	34.5528
61	14	3.5	0.00	0.04	1	74.2445	66.1552	58.8816	53.6465	50.7227	47.9167	44.8529	42.5727	39.9038	37.3957
62	14	3.5	0.00	0.04	2	71.6033	64.3952	59.4961	55.3895	53.5039	51.2252	48.8998	46.6156	43.5135	41.6201
63	14	3.5	0.00	0.04	3	73.0268	65.6168	59.7336	55.4422	53.1026	50.8750	48.4928	46.1644	43.7768	41.1677
64	14	3.5	0.00	0.04	4	72.7396	64.3872	57.7450	52.7680	50.1863	47.5131	44.6897	41.9682	39.0578	36.2460
65	14	3.5	0.00	0.04	5	73.5414	65.0850	58.8173	54.3326	51.9112	49.5472	47.0109	44.3652	41.6168	38.9671
66	14	3.5	0.00	0.06	1	71.8613	63.5808	56.4718	51.7919	48.9596	46.4698	44.1019	41.5966	38.9458	36.5297
67	14	3.5	0.00	0.06	2	71.7213	62.9696	57.2755	52.0833	50.0603	47.7273	45.7405	42.6593	39.6501	37.8378
68	14	3.5	0.00	0.06	3	71.3992	63.3245	57.1429	52.8814	50.5924	48.5185	46.1935	43.9516	41.7598	39.6527
69	14	3.5	0.00	0.06	4	70.8447	63.0397	57.2000	53.0702	50.8046	48.6811	46.5000	44.3433	42.0054	39.7183
70	14	3.5	0.00	0.06	5	70.4657	62.2185	57.0616	53.4430	51.4989	49.4983	47.5087	45.2899	43.1619	40.9367
71	14	3.5	0.00	0.08	1	71.3074	62.5461	52.2353	44.7619	41.4141	38.1098	35.6577	32.4459	28.3951	25.7770
72	14	3.5	0.00	0.08	2	70.7246	60.0345	55.1691	51.6163	49.1785	47.1526	45.4118	43.2069	41.3401	39.3464
73	14	3.5	0.00	0.08	3	71.3398	62.4094	54.8422	49.3902	46.1039	43.6141	40.7989	38.0597	35.1562	32.4104
74	14	3.5	0.00	0.08	4	70.3517	60.2463	53.4979	48.8109	46.5721	43.9901	41.6021	39.1655	36.9596	34.5876
75	14	3.5	0.00	0.08	5	70.9677	64.0306	58.7719	54.9041	52.8428	49.5828	48.5401	46.3198	43.8592	41.5746
76	14	3.5	0.04	0.00	1	76.2162	68.3168	60.0907	53.6232	50.7692	47.2264	44.2155	40.7407	37.1429	33.8346
77	14	3.5	0.04	0.00	2	76.5625	67.4935	61.1486	55.0781	52.3481	48.8889	45.1510	40.8233	38.3929	34.5351
78	14	3.5	0.04	0.00	3	75.6959	66.0019	58.0305	51.9463	48.6370	45.2599	41.5987	38.2759	34.7905	31.5488
79	14	3.5	0.04	0.00	4	76.9545	67.5598	59.1566	52.6536	49.2515	45.4106	41.6523	37.6838	33.7891	29.9587
80	14	3.5	0.04	0.00	5	76.5884	66.5820	61.4773	55.9168	53.1120	50.0000	46.9484	43.6877	40.4218	36.8715
81	14	3.5	0.06	0.00	1	73.5913	63.6768	55.2874	48.4768	42.8781	40.0616	36.5416	34.0678	31.3933	28.4926
82	14	3.5	0.06	0.00	2	70.2923	61.9338	56.6468	52.2404	49.5381	47.4760	44.9622	42.6509	39.8072	37.4821
83	14	3.5	0.06	0.00	3	73.9249	63.5148	53.6406	45.8156	41.7683	37.5817	33.5652	29.5203	26.1122	22.5152
84	14	3.5	0.06	0.00	4	73.5355	64.4115	56.6102	50.5155	47.3251	43.9416	40.3727	36.9458	33.3333	29.7989

CAS	FRESA	PRESB	NUTR	ORZ	REP	W5.0	W5.5	W6.0	W6.5	W7.0	W7.5	W8.0	W8.5	W9.0	Wo
57	12	5.0	0.08	0.00	2	34.3373	31.0127	27.6549	23.9535	18.4539	16.7939	13.2626	10.6557	7.8873	6.83761
58	12	5.0	0.08	0.00	3	29.7794	26.6795	23.7525	21.3992	18.8560	16.7756	14.9220	12.7654	10.9557	6.82927
59	12	5.0	0.08	0.00	4	26.7790	24.0777	21.9000	19.7125	18.0294	15.3680	13.6865	11.9369	10.3211	6.23501
60	12	5.0	0.08	0.00	5	30.6034	26.8182	23.5154	20.4938	17.4359	15.2632	13.2075	11.5365	10.0559	7.20461
61	14	3.5	0.00	0.04	1	34.8958	32.1881	29.5113	26.9006	24.0891	21.5481	19.0065	17.0354	14.5786	7.17822
62	14	3.5	0.00	0.04	2	39.2442	39.0671	33.5453	30.4493	27.9310	24.6847	21.4286	18.1996	15.0407	7.11111
63	14	3.5	0.00	0.04	3	38.5937	36.0976	33.5025	30.9315	28.2847	25.8491	23.2422	20.9256	18.1250	7.09220
64	14	3.5	0.00	0.04	4	33.4992	30.5026	27.6173	25.1866	22.5869	20.2783	18.1633	15.7563	13.5776	6.74419
65	14	3.5	0.00	0.04	5	36.1702	33.2192	30.4813	27.6438	24.7104	22.0000	19.2547	16.6667	14.0965	7.14286
66	14	3.5	0.00	0.06	1	33.8095	30.9603	28.5959	26.0638	23.4862	21.1720	19.0291	16.0966	14.3737	7.33333
67	14	3.5	0.00	0.06	2	35.8140	32.7922	30.1855	27.8746	25.5396	22.7612	20.3846	18.0198	15.1639	7.58929
68	14	3.5	0.00	0.06	3	37.4813	35.2484	32.9582	30.7309	28.3505	26.3251	24.0437	20.6729	19.1860	7.53660
69	14	3.5	0.00	0.06	4	37.6093	35.2496	33.0203	30.9677	28.5476	26.3339	24.6479	22.1818	20.4461	7.15835
70	14	3.5	0.00	0.06	5	38.7009	36.3764	33.9650	31.5710	29.2187	26.8174	24.1206	21.6263	19.1071	7.17213
71	14	3.5	0.00	0.08	1	22.8137	19.9211	17.1429	14.5263	11.9306	9.1723	7.7273	7.3059	6.8807	6.66667
72	14	3.5	0.00	0.08	2	36.8707	34.3706	33.0447	30.8495	28.5054	26.9291	24.6753	21.7538	20.0000	6.45161
73	14	3.5	0.00	0.08	3	29.6610	26.9366	24.5455	21.9925	19.7292	17.3307	15.4786	13.1799	11.5139	6.95067
74	14	3.5	0.00	0.08	4	32.2339	29.5950	27.6800	25.4125	23.2598	21.3913	19.5730	17.6685	15.9851	6.80412
75	14	3.5	0.00	0.08	5	39.9610	36.5817	34.0094	31.4425	28.7879	26.3066	23.5081	20.9346	18.1818	6.62252
76	14	3.5	0.04	0.00	1	29.7405	26.2055	22.9759	18.8940	16.5877	12.8713	11.1111	9.0439	6.8783	6.63130
77	14	3.5	0.04	0.00	2	30.8617	27.5210	23.6726	20.3233	17.0673	13.0982	11.7647	8.0000	7.0081	6.75676
78	14	3.5	0.04	0.00	3	28.4000	25.2610	22.1739	19.1874	16.7442	14.5585	12.2549	10.2757	8.4399	7.73196
79	14	3.5	0.04	0.00	4	26.1438	22.9545	19.4774	16.2963	13.7405	11.7187	9.6000	8.3784	7.8804	7.37705
80	14	3.5	0.04	0.00	5	33.6595	30.2469	26.9397	23.6486	20.4225	17.3171	13.9594	11.0236	8.1301	7.12329
81	14	3.5	0.06	0.00	1	25.3359	22.9703	20.7739	18.7891	16.5236	13.9381	12.3874	10.1617	8.6654	7.15990
82	14	3.5	0.06	0.00	2	34.5808	32.0373	29.4023	26.9231	23.6014	20.8333	18.0113	14.9805	11.8952	6.42398
83	14	3.5	0.06	0.00	3	19.5789	16.0440	14.5414	12.3853	10.5386	8.8305	7.7295	7.2816	7.0560	6.82927
84	14	3.5	0.06	0.00	4	26.2956	22.8916	19.8330	17.2414	14.6667	12.5285	10.6977	9.2199	8.1340	7.24638

OBS	FRESA	PRESB	NLTR	ORZ	REP	W0.0	W0.5	W1.0	W1.5	W2.0	W2.5	W3.0	W3.5	W4.0	W4.5
85	14	3.5	0.06	0.00	5	75.3256	67.5676	60.8696	55.7740	53.0639	50.1385	47.1366	43.8378	40.6915	37.1728
86	14	3.5	0.06	0.00	1	75.7735	66.5428	56.5892	47.9769	44.0124	40.3974	36.9527	32.5843	29.6875	26.3804
87	14	3.5	0.06	0.00	2	72.7335	65.7241	60.6299	56.4744	54.2334	51.8072	49.4311	46.8085	44.9794	41.3490
88	14	3.5	0.06	0.00	3	72.3594	64.5116	54.1524	47.7979	44.4904	41.0819	37.8086	34.2577	30.9932	27.6481
89	14	3.5	0.06	0.00	4	72.7086	64.2793	56.9579	51.2225	48.1144	44.7368	41.2371	37.6562	34.2669	30.4878
90	14	3.5	0.06	0.00	5	72.9564	63.2747	55.6425	50.1256	47.1372	44.1632	41.0979	37.8717	34.9180	31.9039
91	14	5.0	0.00	0.04	1	70.1645	62.1827	56.3050	51.5710	48.7973	47.0379	44.8829	42.7657	40.4000	36.5144
92	14	5.0	0.00	0.04	2	72.4019	64.0681	58.7024	54.0664	51.7449	48.7212	47.1673	44.6133	42.2190	39.1502
93	14	5.0	0.00	0.04	3	72.6899	65.2136	59.4924	55.2189	52.8926	50.6799	48.2490	45.6616	43.2432	40.6250
94	14	5.0	0.00	0.04	4	71.0688	61.8834	55.3102	50.8671	48.6094	46.3384	43.9314	41.6209	39.3723	37.0370
95	14	5.0	0.00	0.04	5	72.0819	64.5581	58.3503	53.9414	51.7119	49.1925	46.8140	44.2019	41.8208	39.2273
96	14	5.0	0.00	0.06	1	71.9892	64.1248	58.7649	54.1528	50.3001	47.8589	44.3548	41.6539	39.2962	36.6972
97	14	5.0	0.00	0.06	2	71.6904	62.1597	56.1514	51.1137	47.4811	46.1935	43.6486	40.9348	38.4047	34.9454
98	14	5.0	0.00	0.06	3	71.6125	63.9104	57.5311	52.9213	50.3555	48.0793	45.6550	43.1479	40.7355	37.9259
99	14	5.0	0.00	0.06	4	70.4209	62.1982	57.3709	77.0359	51.5991	49.4994	47.3318	45.1691	42.9648	40.8083
100	14	5.0	0.00	0.06	5	71.6851	64.1921	58.5020	54.4444	52.3810	50.1217	47.8372	45.4797	43.1345	40.5797
101	14	5.0	0.00	0.08	1	72.2712	63.1532	55.0055	48.7469	44.7297	41.4040	38.5886	34.9762	32.5083	29.1181
102	14	5.0	0.00	0.08	2	72.5924	55.7447	51.4472	47.5277	46.0021	43.4783	41.5730	39.3232	37.0460	35.2428
103	14	5.0	0.00	0.08	3	71.1585	60.3993	55.0519	51.3790	49.5228	47.5193	45.6000	43.4679	41.5233	39.2857
104	14	5.0	0.00	0.08	4	70.8195	59.1463	52.4341	47.5978	45.4016	42.8745	40.5577	38.1266	35.8413	33.3807
105	14	5.0	0.00	0.08	5	70.6600	60.9508	55.0781	50.9072	48.7179	46.3869	44.1069	41.6984	39.3140	36.8132
106	14	5.0	0.04	0.00	1	75.3711	65.2712	55.7576	50.2725	46.3235	40.4568	36.6319	33.7568	30.8712	27.7228
107	14	5.0	0.04	0.00	2	77.5136	70.3671	64.8247	60.0242	57.6184	54.9046	52.0984	48.5198	45.6486	42.4348
108	14	5.0	0.04	0.00	3	72.3948	64.8197	58.4631	53.4342	51.1002	48.3871	45.7995	42.9387	40.2093	37.4022
109	14	5.0	0.04	0.00	4	76.3537	67.0497	58.7814	52.1498	48.5075	43.6275	40.4145	34.4106	32.2200	25.9657
110	14	5.0	0.04	0.00	5	77.2789	66.9307	58.1454	51.3120	47.6489	43.7710	39.8198	35.6455	31.4168	27.2331
111	14	5.0	0.06	0.00	1	74.2344	65.7825	56.8080	50.3209	47.3469	45.6741	43.5850	39.6134	37.3786	34.6284
112	14	5.0	0.06	0.00	2	76.2781	66.2791	58.1227	50.5682	47.3525	43.9614	39.8964	35.9116	32.2957	28.6344

OBS	PRESA	PRESB	NUTR	DR2	REP	W5.0	W5.5	W6.0	W6.5	W7.0	W7.5	W8.0	W8.5	W9.0	We
85	14	3.5	0.06	0.00	5	33.7017	30.0971	26.6802	23.2409	20.0000	16.6667	13.8756	11.1111	8.8608	7.21649
86	14	3.5	0.08	0.00	1	23.2409	20.0000	17.8082	14.6919	11.3300	9.3199	7.9284	7.4550	6.9767	6.73575
87	14	3.5	0.08	0.00	2	37.5000	34.6405	32.4324	29.0780	25.6506	22.3301	18.6992	15.0743	11.3082	7.19258
88	14	3.5	0.08	0.00	3	24.5316	21.4425	18.7500	16.2162	14.0725	12.2004	9.8434	8.6168	8.2005	7.78032
89	14	3.5	0.08	0.00	4	26.7890	23.2692	19.8795	17.0478	14.7436	12.6915	10.7383	9.3162	7.8522	6.99301
90	14	3.5	0.08	0.00	5	28.8530	25.9328	23.5067	20.7585	18.4805	16.0677	14.0693	12.3620	10.1810	7.02576
91	14	5.0	0.00	0.04	1	35.9599	33.9734	31.6514	29.4953	27.1987	25.1256	22.5303	20.4626	18.1319	6.68058
92	14	5.0	0.00	0.04	2	37.0487	34.3699	31.6865	28.9007	26.4220	23.3270	20.7510	17.8279	15.0424	7.17593
93	14	5.0	0.00	0.04	3	37.9471	35.2273	32.3729	29.5053	26.5193	23.5632	20.5179	17.5620	14.1935	7.20930
94	14	5.0	0.00	0.04	4	34.7159	32.0000	29.7521	27.7211	25.3076	23.0072	20.5607	18.2692	16.1736	6.79825
95	14	5.0	0.00	0.04	5	36.7852	33.9257	31.6054	28.9931	26.7025	23.9777	21.7973	19.1700	17.0385	6.62100
96	14	5.0	0.00	0.06	1	34.2857	31.7957	29.3515	26.9841	24.3144	22.4719	19.7674	17.5299	15.5102	7.17489
97	14	5.0	0.00	0.06	2	33.5987	30.8458	28.5959	26.3251	24.1818	21.7636	19.9618	17.7515	16.0966	6.91964
98	14	5.0	0.00	0.06	3	35.8346	33.2803	30.9720	28.4983	26.3620	24.0942	21.9739	19.8853	17.8431	6.88889
99	14	5.0	0.00	0.06	4	38.3152	35.8757	33.6257	31.3162	29.1732	26.6559	24.4552	22.1269	19.9255	6.39175
100	14	5.0	0.00	0.06	5	38.0665	35.4331	32.7869	30.1533	27.5618	24.7706	22.0532	19.4499	17.0040	7.02948
101	14	5.0	0.00	0.08	1	26.3063	23.2645	20.5825	17.5403	15.6701	13.1635	11.0870	8.9087	7.4661	7.04545
102	14	5.0	0.00	0.08	2	32.9897	31.0345	28.7671	26.4498	24.3086	22.1557	20.1229	17.4603	15.1713	7.14286
103	14	5.0	0.00	0.08	3	37.3684	35.1499	33.0520	30.8140	28.3133	26.3158	24.3243	22.3491	19.7302	5.92885
104	14	5.0	0.00	0.08	4	31.3324	28.8316	26.6041	24.5981	22.4793	20.5085	18.7175	16.6963	15.0362	6.20000
105	14	5.0	0.00	0.08	5	34.2857	31.5476	29.0123	26.4000	23.8411	21.2329	18.5841	16.0584	13.5338	6.50407
106	14	5.0	0.04	0.00	1	25.0513	22.0085	19.0687	17.2336	14.9184	13.0952	11.1922	9.6535	8.0605	7.59494
107	14	5.0	0.04	0.00	2	39.0424	34.8425	31.3278	27.0925	22.6636	18.6732	14.6907	11.4973	8.0556	8.05556
108	14	5.0	0.04	0.00	3	34.4262	31.7406	28.6988	25.9259	23.0769	20.4771	17.8645	15.2542	11.8943	6.97674
109	14	5.0	0.04	0.00	4	24.1758	20.3233	17.2662	14.3921	12.2137	10.3896	8.9710	7.2581	7.0081	6.75676
110	14	5.0	0.04	0.00	5	23.0415	19.3237	15.4430	12.5654	10.2151	8.4932	7.9890	7.4792	7.2222	6.96379
111	14	5.0	0.06	0.00	1	31.2611	28.0669	25.0000	20.2062	19.2067	17.3077	13.4228	11.4416	9.1549	7.19424
112	14	5.0	0.06	0.00	2	25.4818	22.1477	17.5355	16.1446	13.8614	10.7692	8.4211	7.9365	7.4468	7.20000

OBS	FRESA	PRESE	NUTR	ORZ	REP	W0.0	W0.5	W1.0	W1.5	W2.0	W2.5	W3.0	W3.5	W4.0	W4.5
113	14	5.0	0.06	0.00	3	72.7397	64.4960	57.2961	51.6990	48.5123	45.4047	42.1512	38.9571	35.4943	32.1976
114	14	5.0	0.06	0.00	4	70.6685	62.4454	55.8974	51.0251	48.5646	45.9799	43.0464	40.1947	37.4090	34.4512
115	14	5.0	0.06	0.00	5	75.0665	67.1053	59.8930	54.2125	51.1719	47.8442	44.4444	41.0377	37.1855	33.3925
116	14	5.0	0.08	0.00	1	72.4436	64.1314	56.4990	52.0785	46.0338	42.8375	39.5924	36.3497	32.3002	29.8986
117	14	5.0	0.08	0.00	2	70.0146	61.5048	56.7780	52.4324	49.5991	46.4068	44.5644	42.3329	39.6433	36.5954
118	14	5.0	0.08	0.00	3	73.6949	65.4804	58.3691	52.6829	49.5449	46.4088	42.9412	39.3750	35.6551	32.1678
119	14	5.0	0.08	0.00	4	73.1691	62.5954	52.6570	45.3278	41.4051	37.5796	33.6717	29.6230	26.0377	22.2222
120	14	5.0	0.08	0.00	5	73.1539	62.4155	53.0193	46.1219	42.3704	38.7402	34.9498	31.2721	27.6952	24.1715
121	16	3.5	0.00	0.04	1	74.8475	66.5162	57.3072	50.8609	47.1510	44.5441	41.5748	38.3721	35.4783	32.5455
122	16	3.5	0.00	0.04	2	74.7606	65.0237	58.0205	51.7647	49.3827	46.5991	42.1630	39.4089	37.2449	33.3535
123	16	3.5	0.00	0.04	3	72.5357	64.4366	57.4737	52.4146	49.5630	46.6314	43.8108	40.9357	37.9416	34.9436
124	16	3.5	0.00	0.04	4	70.9096	59.6567	53.7856	49.9468	48.0088	45.8525	43.7126	41.5423	39.5887	37.4168
125	16	3.5	0.00	0.04	5	73.4386	65.9631	60.0207	55.5683	53.2044	50.8883	48.1233	45.6741	43.1718	38.6688
126	16	3.5	0.00	0.06	1	70.7917	60.3041	52.6687	48.8017	46.6515	44.4444	42.3313	40.2036	37.9128	35.8759
127	16	3.5	0.00	0.06	2	70.2171	60.6631	53.7895	50.7295	48.4136	45.4658	43.2083	40.7557	38.4292	35.9124
128	16	3.5	0.00	0.06	3	74.7103	66.8157	60.2784	55.3012	52.5575	49.7970	46.9242	44.0422	41.0175	37.9559
129	16	3.5	0.00	0.06	4	70.4396	61.1966	56.0928	51.9577	49.8343	47.6355	45.2352	43.0364	40.8083	38.4824
130	16	3.5	0.00	0.06	5	73.2293	56.2258	50.9074	47.0646	45.0203	43.0526	41.0675	38.8701	36.6511	34.6618
131	16	3.5	0.00	0.08	1	72.5017	63.1626	54.9451	49.6314	46.8223	44.0655	41.5121	38.8972	36.4341	33.7641
132	16	3.5	0.00	0.08	2	70.3516	61.2903	56.1538	52.5494	50.1639	48.2406	46.6667	44.0491	41.8367	40.0000
133	16	3.5	0.00	0.08	3	70.8098	60.6973	55.2481	51.3990	49.3521	47.3034	45.2103	43.1515	41.1543	39.0117
134	16	3.5	0.00	0.08	4	71.2237	58.1375	51.9000	47.7174	45.4649	43.3451	40.8364	38.6480	36.2914	34.3793
135	16	3.5	0.00	0.08	5	72.1138	59.1459	54.1176	50.5366	48.5279	46.7437	44.7110	42.7765	40.5627	38.4709
136	16	3.5	0.04	0.00	1	70.1743	63.0104	56.3739	52.1244	49.3976	47.0183	44.2702	42.0326	39.5288	37.0572
137	16	3.5	0.04	0.00	2	70.4561	60.6684	55.0259	50.2294	47.2661	44.7134	42.3639	39.3007	36.7347	33.8415
138	16	3.5	0.04	0.00	3	75.0518	63.9361	53.5990	45.2200	40.8197	35.7651	31.1069	26.6260	22.1983	18.1406
139	16	3.5	0.04	0.00	4	76.3860	69.0305	62.6219	57.3548	54.5455	51.4085	48.1982	44.6228	41.3265	37.6130
140	16	3.5	0.04	0.00	5	75.3283	66.6978	59.4318	53.8760	50.9615	47.8832	44.8223	41.5712	36.5542	35.3261

CPS	FRESA	PRESB	NUTR	DRZ	REP	W5.0	W5.5	W6.0	W6.5	W7.0	W7.5	W8.0	W8.5	W9.0	Wo
113	14	5.0	0.08	0.00	3	29.6738	25.4682	22.1135	19.2698	16.0338	12.5275	10.9620	8.9245	7.0093	6.79157
114	14	5.0	0.08	0.00	4	31.5287	28.2137	25.0871	22.2423	19.6262	16.9884	14.5129	12.2449	9.8532	6.72451
115	14	5.0	0.08	0.00	5	29.5113	25.7426	22.1992	18.6551	15.3499	12.3832	9.8558	7.4074	6.5475	6.48375
116	14	5.0	0.08	0.00	1	26.4184	22.8625	20.3455	17.0000	14.7844	12.4473	10.7527	9.1904	8.3885	7.57238
117	14	5.0	0.08	0.00	2	33.9339	31.0345	28.3388	25.1701	22.3986	19.2661	16.0305	11.6466	9.8361	6.77966
118	14	5.0	0.08	0.00	3	29.4133	24.2188	20.8163	17.7966	14.5374	11.4155	8.7059	6.7308	4.6683	6.95444
119	14	5.0	0.08	0.00	4	18.8406	15.5172	12.8889	10.7062	8.6247	8.1967	7.9812	7.7647	7.5472	7.32861
120	14	5.0	0.08	0.00	5	20.7739	17.9325	15.2505	12.5843	10.7798	8.8993	7.6010	7.1599	6.9378	6.71463
121	16	3.5	0.00	0.04	1	29.7348	26.5347	23.9754	21.5645	19.4615	17.9204	13.3178	12.2931	9.5122	7.25000
122	16	3.5	0.00	0.04	2	31.2849	27.7886	25.7545	22.8033	21.6561	15.9453	14.9770	11.0843	10.6538	6.58228
123	16	3.5	0.00	0.04	3	31.8716	28.9982	26.0073	23.1939	20.4724	17.7189	14.9474	12.3644	10.0223	7.12644
124	16	3.5	0.00	0.04	4	35.3508	33.1437	30.9824	28.5714	26.5625	24.3156	22.1854	20.0680	17.9756	6.00000
125	16	3.5	0.00	0.04	5	37.5806	34.8485	32.1053	29.5082	26.7045	23.9686	21.3415	18.8679	15.8696	7.41627
126	16	3.5	0.00	0.06	1	33.7094	31.4869	29.3233	27.0186	24.5586	22.1854	20.2037	18.4028	16.0714	6.56064
127	16	3.5	0.00	0.06	2	33.6958	31.2989	29.0792	26.5886	24.1796	21.8861	19.7441	17.4812	15.0870	6.39659
128	16	3.5	0.00	0.06	3	35.0263	32.1755	28.3784	26.0956	23.3471	20.5567	17.7384	15.6818	13.5198	7.25000
129	16	3.5	0.00	0.06	4	35.6028	33.2353	30.7927	29.9383	26.1789	23.8255	21.4533	19.0731	17.0018	6.19835
130	16	3.5	0.00	0.06	5	32.4594	30.1935	28.0585	25.8904	23.8028	21.5942	19.3741	17.1516	15.0706	7.04467
131	16	3.5	0.00	0.08	1	31.0924	27.9438	25.8590	23.5075	21.1538	18.8119	16.3265	14.4050	12.0172	7.44921
132	16	3.5	0.00	0.08	2	36.8421	35.0427	32.7434	30.3817	28.0757	25.2459	22.8426	20.2797	17.9856	6.17284
133	16	3.5	0.00	0.08	3	36.7925	34.8611	32.6149	30.5185	28.2875	26.2579	24.3548	22.0930	20.2381	6.20000
134	16	3.5	0.00	0.08	4	31.9651	29.9854	27.8861	25.8860	24.1325	22.0421	20.3642	18.7500	17.2117	5.87084
135	16	3.5	0.00	0.08	5	36.1461	33.9844	31.6712	28.6920	26.9452	24.4411	22.1198	19.6513	17.1569	7.14286
136	16	3.5	0.04	0.00	1	34.3750	32.0588	29.0323	26.3158	23.5099	20.6186	17.7936	14.7601	12.1673	6.28803
137	16	3.5	0.04	0.00	2	30.5600	28.3828	25.6849	23.0496	20.2206	17.4905	14.5669	11.7886	9.0147	6.46552
138	16	3.5	0.04	0.00	3	14.4550	11.9512	9.5238	7.4359	7.1579	6.7183	6.4767	6.2338	5.9896	5.74413
139	16	3.5	0.04	0.00	4	34.1603	30.1619	26.7516	22.9911	19.9536	16.6667	14.1791	11.7647	9.4488	6.75676
140	16	3.5	0.04	0.00	5	32.0000	28.8845	25.7796	22.8942	20.1342	17.5520	15.4028	13.1387	11.1940	7.27273

OBS	FAESA	HPESB	NUTR	ORZ	REP	W0.0	W0.5	W1.0	W1.5	W2.0	W2.5	W3.0	W3.5	W4.0	W4.5
141	16	3.5	0.06	0.00	1	76.1612	68.9778	59.0856	52.2572	49.6392	46.7988	43.4360	40.0344	36.1974	32.8846
142	16	3.5	0.06	0.00	2	72.4091	62.9493	56.3991	51.1543	48.1959	45.6022	41.3994	40.4444	37.2855	35.0565
143	16	3.5	0.06	0.00	3	72.9693	65.1715	58.7500	53.9535	51.2315	48.5714	45.6790	42.9395	40.2715	37.0429
144	16	3.5	0.06	0.00	4	74.0741	63.8623	54.9464	48.1481	44.6559	40.6593	36.7893	32.8597	28.8136	25.4438
145	16	3.5	0.06	0.00	5	74.5681	64.7510	57.1595	51.8325	49.1010	46.2774	43.3846	40.2597	37.5212	34.6359
146	16	3.5	0.08	0.00	1	75.5297	65.1751	57.1257	46.8053	41.7886	38.2759	34.1912	31.4176	28.4000	24.1525
147	16	3.5	0.08	0.00	2	75.6646	65.5072	57.2455	50.2786	46.8750	42.8800	39.2857	35.4430	31.7400	28.3123
148	16	3.5	0.08	0.00	3	74.3169	64.8926	56.6321	50.2646	46.6667	43.1165	39.4525	35.9455	32.1300	28.6528
149	16	3.5	0.08	0.00	4	71.4384	62.7679	55.4487	49.9400	46.9466	43.9516	40.8511	37.8539	34.8438	31.7512
150	16	3.5	0.08	0.00	5	70.1644	62.4579	56.6990	52.2995	50.0000	47.5294	44.9383	42.3773	39.4844	36.5576
151	16	5.0	0.00	0.04	1	71.8414	64.6712	58.4325	54.8491	53.1320	48.5890	46.2821	44.0587	41.5621	39.1872
152	16	5.0	0.00	0.04	2	71.8247	59.1503	54.9955	50.8841	49.6475	47.2574	46.0043	44.0716	42.1965	40.2628
153	16	5.0	0.00	0.04	3	73.1507	65.2174	59.1667	54.5771	52.1368	49.5495	46.9553	44.3972	41.6667	38.9408
154	16	5.0	0.00	0.04	4	75.1362	66.2350	58.6166	53.6802	51.0067	48.2270	45.3593	42.7002	39.7690	36.3002
155	16	5.0	0.00	0.04	5	70.0088	63.6139	58.5915	54.8618	52.9851	50.7263	49.0173	46.6102	44.6675	41.9737
156	16	5.0	0.00	0.06	1	71.6317	64.3404	58.4325	54.3573	52.6554	50.5313	48.2716	46.2131	43.6826	40.9859
157	16	5.0	0.00	0.06	2	70.8799	61.5385	57.5812	54.3246	52.5732	50.8882	49.1342	47.5446	47.4860	43.2367
158	16	5.0	0.00	0.06	3	72.5784	63.9462	57.0513	52.0858	49.5609	46.9657	44.3213	41.6546	38.9056	36.4929
159	16	5.0	0.00	0.06	4	72.3805	57.8647	53.1703	49.5610	47.6190	45.6362	43.6819	41.6479	39.5322	37.3333
160	16	5.0	0.00	0.06	5	71.0030	60.8444	55.7116	52.1255	49.5736	48.2495	46.1276	43.9573	41.8204	39.5141
161	16	5.0	0.00	0.08	1	73.7738	66.2281	57.1746	52.2924	50.1540	47.6902	45.1567	42.5373	39.7496	36.7816
162	16	5.0	0.00	0.08	2	71.3398	59.0871	54.4256	50.2058	48.3458	46.1624	44.3038	42.1053	40.0990	38.0282
163	16	5.0	0.00	0.08	3	70.7036	60.4274	54.6076	50.5870	48.4410	46.2877	44.2840	42.1250	40.0259	37.9357
164	16	5.0	0.00	0.08	4	72.5158	64.5815	58.3420	53.7931	51.3317	48.7245	46.1126	43.2203	40.6204	37.7709
165	16	5.0	0.00	0.08	5	74.0136	65.3043	58.7473	49.5376	51.3376	48.7936	46.0452	43.1548	40.4056	37.6835
166	16	5.0	0.04	0.00	1	76.7410	66.2070	59.1934	49.5601	44.7833	40.9949	37.2263	33.5907	29.0722	25.5411
167	16	5.0	0.04	0.00	2	76.4706	68.2070	62.5680	57.1606	54.9738	52.3546	49.5601	45.7413	33.2039	37.4545
168	16	5.0	0.04	0.00	3	77.5815	69.1300	61.2221	54.7945	50.9658	47.2843	43.0052	38.8889	33.8677	29.9363

OBS	FRESA	PRESB	NUTR	ORZ	REP	W5.0	W5.5	W6.0	W6.5	W7.0	W7.5	W8.0	W8.5	W9.0	We
141	16	3.5	0.06	0.00	1	29.2089	25.7447	21.7489	18.8372	16.1058	13.1841	10.7417	8.1579	7.6720	7.18085
142	16	3.5	0.06	0.00	2	32.5503	30.2083	27.6978	25.1397	22.6923	19.9203	17.4538	14.6305	12.2271	6.72854
143	16	3.5	0.06	0.00	3	34.2193	31.2500	28.2609	25.2830	22.5049	19.8381	16.9811	14.0998	12.0000	7.04225
144	16	3.5	0.06	0.00	4	21.2500	18.3585	15.0562	12.5000	10.4265	8.4746	7.3529	6.8966	6.6667	6.43564
145	16	3.5	0.06	0.00	5	31.8519	28.9575	26.1044	23.4927	21.0300	18.4035	16.3636	14.2191	12.5891	7.07071
146	16	3.5	0.08	0.00	1	22.3427	19.5508	17.3210	14.9644	13.5266	11.3861	8.2051	7.9692	7.4935	7.01299
147	16	3.5	0.08	0.00	2	23.8806	20.8426	17.7419	14.3885	11.6337	7.9897	7.7519	7.2727	7.0312	6.78851
148	16	3.5	0.08	0.00	3	25.2485	21.8295	18.7905	16.0714	12.9630	10.9005	8.7379	7.1605	6.9307	6.69975
149	16	3.5	0.06	0.00	4	28.4734	25.2688	22.2015	19.3424	16.6000	14.0206	11.6525	9.3478	7.3333	6.91964
150	16	3.5	0.08	0.00	5	32.6310	30.5296	27.3616	24.4068	21.3404	18.1651	15.0476	11.8577	8.9796	6.49895
151	16	5.0	0.00	0.04	1	36.8024	34.3260	31.6476	28.8625	26.7483	24.3682	21.8284	19.2678	17.1937	7.09534
152	16	5.0	0.00	0.04	2	38.0421	35.8151	33.9498	31.2242	29.5775	27.2198	24.9249	22.4806	20.1278	7.06320
153	16	5.0	0.00	0.04	3	36.2602	33.3333	30.4965	27.6753	24.9042	22.2222	19.6721	16.7728	14.5969	7.32861
154	16	5.0	0.00	0.04	4	34.2342	31.5197	28.8499	26.5594	24.1164	21.8415	19.6035	17.4208	15.5093	7.12468
155	16	5.0	0.00	0.04	5	39.4231	37.2688	34.8597	31.5217	29.2135	26.1307	23.3043	20.3971	17.1053	7.15789
156	16	5.0	0.00	0.06	1	38.8321	36.3222	33.8073	31.0855	28.3761	25.4448	22.8361	19.6853	17.0297	7.09534
157	16	5.0	0.00	0.06	2	41.9036	39.9745	38.0764	36.0544	33.7094	31.7852	29.3233	27.3570	25.2782	6.93069
158	16	5.0	0.00	0.06	3	33.5537	30.9278	27.6978	25.5556	22.9885	20.3960	16.9421	15.5462	12.7983	7.37327
159	16	5.0	0.00	0.06	4	35.1317	33.1177	30.8824	28.4924	26.3533	24.0822	21.9033	19.4704	17.1474	7.18133
160	16	5.0	0.00	0.06	5	37.1846	34.0685	32.2350	29.7177	27.2308	24.5614	21.9472	19.5578	16.7254	7.25450
161	16	5.0	0.00	0.08	1	33.1597	31.2500	27.2212	25.8189	23.3068	20.9446	17.9104	15.5702	12.6984	7.00483
162	16	5.0	0.00	0.08	2	34.2391	32.4022	30.6590	28.8235	26.5554	24.2567	22.0612	19.4676	17.1233	7.10173
163	16	5.0	0.00	0.08	3	35.6944	33.6676	31.7109	29.5282	27.2013	25.4428	23.4711	21.6582	19.6181	6.46465
164	16	5.0	0.00	0.08	4	34.7403	31.7487	29.3497	26.5082	23.5741	21.1765	18.6235	16.2500	14.1026	7.37327
165	16	5.0	0.00	0.08	5	34.7009	32.0285	29.1280	26.3969	23.9044	21.7213	19.0678	15.6733	14.9220	7.28155
166	16	5.0	0.04	0.00	1	22.5225	18.6761	15.8924	12.2449	10.6494	8.0214	7.5269	7.0270	6.7751	6.52174
167	16	5.0	0.04	0.00	2	37.9061	33.9462	30.6452	27.8826	24.5614	19.6262	17.8598	14.4279	9.5476	8.02139
168	16	5.0	0.04	0.00	3	25.5079	21.2411	17.0654	13.6126	10.3261	7.8212	7.8212	7.3034	7.0423	6.77966

CAS	FRESA	PRESH	NUTR	GRZ	REP	W0.0	W0.5	W1.0	W1.5	W2.0	W2.5	W3.0	W3.5	W4.0	W4.5
169	16	5	0.04	0	4	71.6530	62.9795	56.1311	51.1765	48.5750	45.9635	43.3060	40.6295	37.7811	35.2574
170	16	5	0.04	0	5	71.8019	63.5231	56.6875	52.1028	49.5695	46.8223	44.2177	41.5121	38.7145	35.7367
171	16	5	0.06	0	1	73.1563	64.5914	55.9322	48.4419	43.1250	39.0285	34.7670	32.2160	29.0448	25.7143
172	16	5	0.06	0	2	75.0155	67.5676	61.1173	55.3273	52.0661	48.9736	45.6250	42.1527	38.2979	34.9533
173	16	5	0.06	0	3	73.5172	62.7184	52.3573	44.8276	40.8320	36.8421	32.7496	28.8889	25.1462	21.3115
174	16	5	0.06	0	4	74.3502	64.3197	54.8193	47.5524	43.6090	39.4184	35.2332	31.3187	27.3256	23.1557
175	16	5	0.06	0	5	74.6731	65.7674	58.0866	52.3316	49.2414	45.7227	42.4100	38.9718	35.4386	31.7254
176	16	5	0.08	0	1	72.9749	65.5083	58.3876	51.3480	51.4076	49.1677	46.4960	43.7677	40.9226	37.4803
177	16	5	0.08	0	2	75.3731	66.1064	59.1216	53.2216	50.3420	46.4602	44.1538	40.5892	37.6289	33.0258
178	16	5	0.08	0	3	70.8209	60.0680	53.9216	49.4080	47.1316	44.6408	41.9753	39.3548	36.7429	34.0813
179	16	5	0.08	0	4	70.7394	60.3952	54.1294	49.6175	47.1330	44.6579	42.2306	39.5806	37.0219	34.3305
180	16	5	0.08	0	5	73.8324	62.5737	52.9630	45.8037	41.9207	37.8467	33.5688	30.2198	26.4479	22.7181

OBS	PRESA	PRESB	NUTR	ORZ	REP	W5.0	W5.5	W6.0	W6.5	W7.0	W7.5	W8.0	W8.5	W9.0	We
169	16	5	0.04	0	4	32.1895	29.5416	26.8078	24.1316	21.4015	18.6275	16.1616	13.5417	10.9442	7.15684
170	16	5	0.04	0	5	32.7869	29.9145	27.0463	24.3542	22.0532	19.2913	16.6667	14.4050	12.3932	7.02946
171	16	5	0.06	0	1	22.7176	19.2905	17.0843	14.3529	12.0773	9.4527	7.3791	7.1429	6.9054	6.66667
172	16	5	0.06	0	2	30.9524	27.0440	23.1788	19.8157	15.7385	13.2170	9.8446	7.9365	7.4468	7.20000
173	16	5	0.06	0	3	18.2979	15.0442	12.5285	9.8592	8.5714	8.1340	7.6923	7.4695	7.2464	7.02179
174	16	5	0.06	0	4	19.8718	16.6667	14.1876	11.9718	10.0719	8.7591	7.4074	7.1782	6.9479	6.71642
175	16	5	0.06	0	5	25.2651	24.7444	21.3675	18.5841	15.5963	12.7962	10.6796	8.2294	7.0707	7.30479
176	16	5	0.08	0	1	34.9180	32.0205	28.3394	25.3759	22.3092	19.1446	15.7113	13.3188	9.9773	7.02576
177	16	5	0.08	0	2	30.8571	25.7669	25.0000	23.7395	19.5122	16.5517	14.5882	12.5301	10.5911	7.16113
178	16	5	0.08	0	3	30.9838	28.5714	25.6329	22.9508	20.2037	17.1076	14.8551	12.6394	10.1338	6.93069
179	16	5	0.08	0	4	31.3988	28.8580	25.8842	23.2945	20.5172	17.9715	15.2574	12.3574	9.9609	6.68016
180	16	5	0.08	0	5	19.2797	16.2637	13.8009	11.3953	9.7156	7.5243	7.2993	7.0732	6.8460	6.61765

OBS Observation number associated with a particular piece of data

PRESA - Crushing roll pressure, first set of rolls (kg/cm)

PRESB - Batting roll pressure, second set of rolls (kg/cm)

NUTR - Nutri-Binder (%)

ORZ - Orzan G (%)

REP - Replication number

Wt - Moisture content, wet basis, at elapsed time t (t = 0.0 to 9.0 hour)

We - Equilibrium moisture content, wet basis (%)

OBS	PRESA	PRESB	NUTR	ORZ	REP	W0.0	W0.5	W1.0	W1.5	W2.0	W2.5	W3.0	W3.5	W4.0	W4.5
1	0	0	0	0	1	78.1335	74.2786	71.3649	67.9960	66.5973	65.7417	64.5304	63.1034	61.5569	59.2640
2	0	0	0	0	2	80.3010	74.6702	72.0388	68.7636	67.0103	65.2593	63.1242	61.0811	58.9158	56.7568
3	0	0	0	0	3	78.8540	74.3590	71.6895	68.6869	67.0213	65.1685	63.2701	61.3466	59.3176	57.1823
4	0	0	0	0	4	73.3710	74.9405	72.8988	70.4120	69.1707	67.7551	66.3472	64.7715	63.1702	61.5104
5	0	0	0	0	5	79.1580	74.5791	71.6165	68.3770	66.5188	64.6784	62.6700	60.5744	58.4594	56.3584
6	12	0	0	0	1	78.7291	70.2247	62.0525	54.1126	49.6835	46.0102	41.6514	38.0117	34.0249	30.1099
7	12	0	0	0	2	78.1955	71.3387	65.7725	61.1922	58.6788	56.1210	53.2943	50.3888	47.5329	44.2308
8	12	0	0	0	3	79.0366	70.0000	61.3267	54.2222	50.4808	46.5398	42.2430	38.0762	33.6910	29.6128
9	12	0	0	0	4	77.7170	70.5510	64.2935	59.1990	56.3588	53.4950	50.4559	47.2492	43.7931	40.2930
10	12	0	0	0	5	74.5728	68.3135	63.0219	58.8950	56.6434	53.7888	51.9380	49.1108	46.3203	43.4650
11	14	0	0	0	1	76.5085	70.7024	62.3068	55.4149	51.2308	47.6033	43.1900	39.5038	35.5691	31.6810
12	14	0	0	0	2	79.5470	71.2633	65.0645	59.5658	56.9986	53.7267	50.7438	47.1631	43.7736	38.9344
13	14	0	0	0	3	78.4793	71.5184	65.4684	60.5721	58.0132	55.0355	52.1870	48.8710	45.6261	42.1533
14	14	0	0	0	4	78.4932	69.1855	60.3535	53.0643	49.1909	44.8155	40.5303	36.0489	31.4410	27.1462
15	14	0	0	0	5	76.3699	70.0261	64.2116	59.6019	56.9825	54.3046	51.4085	48.2759	45.1510	41.7230
16	16	0	0	0	1	73.6413	65.2952	57.1271	51.5605	49.2147	46.4088	42.5185	40.2157	37.2168	33.9012
17	16	0	0	0	2	78.8540	69.6078	61.4907	55.0073	52.3810	49.0969	44.4444	41.8386	38.3699	34.3220
18	16	0	0	0	3	77.7929	69.6179	62.2248	56.1828	52.9582	49.3789	46.1157	42.5044	38.9513	35.3175
19	16	0	0	0	4	78.1293	67.3846	56.9106	48.5437	44.0141	39.4286	34.9693	30.5677	26.0465	22.0588
20	16	0	0	0	5	75.9450	68.4968	61.7486	56.5217	53.7037	50.7042	47.6831	44.1786	40.7783	37.1634

OBS	PRESA	PRESB	NUTR	ORZ	REP	W5.0	W5.5	W6.0	W6.5	W7.0	W7.5	W8.0	W8.5	W9.0	W0
1	0	0	0	0	1	58.2031	56.3859	54.7250	53.0015	51.1416	49.3691	47.5490	46.0504	44.2708	6.95652
2	0	0	0	0	2	54.6457	52.3179	50.3448	48.1081	45.8647	43.7500	42.4000	40.3727	38.9831	7.09677
3	0	0	0	0	3	55.0725	52.8156	50.6369	48.4193	46.1806	44.1441	42.2719	40.1544	38.4921	7.18563
4	0	0	0	0	4	59.7964	57.9787	56.1720	54.2692	52.5526	50.7788	49.1143	47.4210	45.7976	7.05882
5	0	0	0	0	5	54.0335	51.7572	49.9171	48.1100	46.3588	44.7898	43.0189	41.2451	39.8406	7.07692
6	12	0	0	0	1	26.2181	22.8155	19.2893	16.3158	13.5870	11.4206	9.1429	7.5581	7.2886	7.01754
7	12	0	0	0	2	41.0351	37.3281	34.0909	30.1969	27.0023	23.1325	19.8492	16.0526	13.0790	6.99708
8	12	0	0	0	3	25.7212	21.7722	18.4697	15.3425	12.2159	10.1744	8.0357	7.7612	7.4850	6.92771
9	12	0	0	0	4	36.8217	33.6049	30.1927	27.0694	24.0093	21.0654	18.2957	15.9794	13.7566	7.12251
10	12	0	0	0	5	40.4800	37.3737	34.3915	30.9833	27.6265	24.3902	20.6823	17.5166	14.0878	6.53266
11	14	0	0	0	1	27.1264	23.6145	18.9258	16.1376	12.4309	9.6866	7.3099	6.7647	6.4897	6.21302
12	14	0	0	0	2	35.9140	32.5792	28.8783	24.7475	20.5333	15.0997	12.3529	10.5105	7.4534	7.16511
13	14	0	0	0	3	38.6847	34.6392	31.3853	27.2936	23.6145	19.9495	15.9151	13.3880	10.1983	7.03812
14	14	0	0	0	4	22.8501	19.2802	16.4894	13.2597	11.5493	9.7701	8.4548	7.9179	7.6471	7.37463
15	14	0	0	0	5	38.2826	34.9057	31.4115	27.9243	24.1758	20.6897	16.8675	13.5338	10.1562	7.00809
16	16	0	0	0	1	30.7143	26.7925	24.2188	21.1382	17.7966	14.9123	11.6173	8.4906	7.8385	7.17703
17	16	0	0	0	2	30.6488	26.3656	23.2673	18.6352	14.3646	12.9213	8.5546	7.7381	7.4627	7.18563
18	16	0	0	0	3	31.3684	27.7162	24.1860	20.8738	17.6768	14.4357	11.6531	9.4444	7.6487	7.38636
19	16	0	0	0	4	18.2519	15.4255	13.1148	10.9244	9.1429	7.8261	7.5561	7.2886	7.0175	6.74487
20	16	0	0	0	5	33.7121	30.0000	26.3158	22.5664	18.9815	15.6627	12.5000	9.6162	7.8947	6.91489

APPENDIX B

EXPERIMENTAL VALUES OF THE DRYING CONSTANT AND DRY MATTER LOSS FOR HAY BATTING (WITH BINDER)

TABLE XI

EXPERIMENTAL VALUES OF THE DRYING CONSTANT K FOR HAY BATTING

Crushing Roll Pressure (kg/cm)	Batting Roll Pressure (kg/cm)	Nutri Binder (%)	Orzan (%)	Values of K (Hour $^{-1}$) For Five Replications*					Average K (Hour $^{-1}$)
12	3.5	0	4	0.427	0.319	0.419	0.345	0.321	0.366
		0	6	0.356	0.383	0.362	0.275	0.293	0.333
		0	8	0.370	0.348	0.315	0.276	0.288	0.319
		4	0	0.381	0.578	0.339	0.386	0.511	0.439
		6	0	0.420	0.382	0.374	0.320	0.333	0.365
		8	0	0.458	0.400	0.486	0.445	0.627	0.404
	5.0	0	4	0.307	0.293	0.335	0.302	0.283	0.304
		0	6	0.340	0.351	0.388	0.327	0.344	0.350
		0	8	0.399	0.278	0.376	0.367	0.281	0.340
		4	0	0.364	0.611	0.709	0.530	0.603	0.563
		6	0	0.569	0.380	0.750	0.297	0.568	0.512
		8	0	0.500	0.474	0.425	0.437	0.477	0.462
14	3.5	0	4	0.369	0.315	0.315	0.367	0.357	0.344
		0	6	0.358	0.341	0.306	0.294	0.278	0.315
		0	8	0.595	0.275	0.399	0.332	0.294	0.379
		4	0	0.484	0.491	0.513	0.579	0.464	0.506
		6	0	0.489	0.345	0.630	0.516	0.446	0.485
		8	0	0.597	0.335	0.557	0.501	0.432	0.484
	5.0	0	4	0.299	0.336	0.337	0.330	0.332	0.327
		0	6	0.346	0.345	0.320	0.271	0.314	0.319
		0	8	0.513	0.296	0.265	0.331	0.326	0.346

TABLE XI (Continued)

Crushing Roll Pressure (kg/cm)	Batting Roll Pressure (kg/cm)	Nutri Binder (%)	Orzan (%)	Values of K (Hour $^{-1}$) For Five Replications*					Average K (Hour $^{-1}$)
		4	0	0.549	0.421	0.368	0.585	0.640	0.512
		6	0	0.447	0.577	0.465	0.397	0.532	0.483
		8	0	0.515	0.374	0.492	0.676	0.611	0.533
16	3.5	0	4	0.452	0.428	0.410	0.289	0.338	0.383
		0	6	0.313	0.332	0.381	0.299	0.291	0.323
		0	8	0.398	0.288	0.273	0.306	0.274	0.307
		4	0	0.345	0.398	0.719	0.438	0.426	0.465
		6	0	0.541	0.376	0.380	0.614	0.407	0.463
		8	0	0.600	0.614	0.555	0.484	0.378	0.526
	5.0	0	4	0.321	0.254	0.353	0.374	0.289	0.318
		0	6	0.308	0.230	0.376	0.276	0.289	0.295
		0	8	0.379	0.290	0.284	0.360	0.370	0.336
		4	0	0.637	0.421	0.630	0.389	0.376	0.490
		6	0	0.618	0.513	0.677	0.636	0.508	0.590
		8	0	0.393	0.439	0.377	0.373	0.653	0.447

*Values of K found from statistical fitting of experimental data to the model MR = EXP ($-K\theta$).

TABLE XII

DRY MATTER LOSS FOR HAY BATTING (WITH BINDER)

Crushing Roll Pressure (kg/cm)	Batting Roll Pressure (kg/cm)	Nutri Binder (%)	Orzan (%)	Values of Dry Matter Losses (%) For Five Replications*					Average (%)
12	3.5	0	4	5.2	4.2	7.3	5.2	4.1	5.2
		0	6	4.5	5.4	4.6	2.8	5.3	4.5
		0	8	5.1	4.4	5.0	2.5	5.0	4.4
		4	0	9.1	7.4	8.4	8.7	8.4	8.4
		6	0	9.4	10.2	6.1	6.8	10.0	8.5
		8	0	8.5	8.7	7.6	8.6	8.1	8.3
	5.0	0	4	4.8	5.3	4.9	6.4	4.6	5.2
		0	6	5.8	3.0	3.5	4.0	4.9	4.2
		0	8	5.0	4.6	4.7	6.5	3.6	4.9
		4	0	7.7	9.0	8.6	6.1	7.9	7.9
		6	0	13.3	12.5	12.4	12.7	13.5	12.8
		8	0	8.2	5.8	8.3	5.5	8.4	7.2
14	3.5	0	4	6.5	8.9	5.9	6.7	8.3	7.3
		0	6	5.4	6.9	5.4	2.7	4.6	5.0
		0	8	2.3	5.4	3.3	4.8	6.2	4.4
		4	0	9.5	11.5	9.0	11.9	9.4	10.3
		6	0	6.2	6.7	11.4	9.9	12.6	9.4
		8	0	12.4	9.6	9.5	13.4	14.7	11.9
	5.0	0	4	7.0	8.3	3.6	5.7	6.0	6.1
		0	6	6.8	5.3	6.0	6.0	5.6	5.9
		0	8	4.7	5.2	7.1	3.2	5.8	5.2
		4	0	10.0	12.0	11.3	11.3	10.4	11.0
		6	0	11.7	10.1	8.7	9.0	10.2	9.9
		8	0	10.8	11.2	11.8	12.0	11.0	11.4

TABLE XII (Continued)

Crushing Roll Pressure (kg/cm)	Batting Roll Pressure (kg/cm)	Nutri Binder (%)	Orzan (%)	Values of Dry Matter Losses (%) For Five Replications*					Average (%)
16	3.5	0	4	9.7	7.1	6.0	8.2	3.8	7.0
		0	6	7.5	5.4	7.3	3.4	3.2	5.4
		0	8	3.7	7.8	5.5	5.2	5.4	5.5
		4	0	7.5	8.5	11.0	11.6	12.5	10.2
		6	0	10.6	11.0	12.2	11.4	8.7	10.8
		8	0	10.8	9.8	11.9	11.2	11.8	11.1
	5.0	0	4	6.7	6.5	5.5	4.6	9.0	6.5
		0	6	7.3	5.6	6.4	3.9	4.7	5.6
		0	8	7.7	7.2	2.8	2.6	4.7	5.0
		4	0	9.2	10.8	6.1	4.7	5.2	7.2
		6	0	12.6	10.1	6.9	10.0	9.4	9.7
		8	0	10.9	11.1	8.0	9.2	9.8	9.8

*Values of dry matter losses found from pickup unit experiment for hay batting.

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