STRAIGHT COMBINING AND DRYING - AN ALTERNATIVE TO WINDROWING

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INTRODUCTION

Cereal grain harvesting in Western Canada has been done almost exclusively with the windrower and combine for the last 25 years. Many farmers are now looking for a harvesting system which depends less on natural field drying, as excessive wet weather has caused frequent difficulties and occasional disasters. Since heated air dryers are now commonly used in some areas and are considered part of a normal harvesting operation, the dryer may eventually replace the windrower on many farms. In addition, natural air bin drying shows considerable promise for grains harvested at 20% moisture or less.

Before farmers will accept any changes from present windrowing and harvesting practices, the agronomic, mechanical and economic feasibility of the new practice must be proven. Past research provides answers to many of the questions, but much of the research is outdated and no longer relevant. Substantial research will be required, however, before all the questions are answered and the practice of straight combining and drying is shown to be viable. In addition, since farming practices vary widely across the soil zones, a comprehensive study of harvesting systems based on new research is required to optimize machinery use.

OBJECTIVE

The purpose of this paper was to investigate different harvesting practices by reviewing available literature, to determine feasible alternatives to present harvesting practices, and to outline research required to improve the harvesting process.

SCOPE

Canadian, American and European literature on windrowing, straight cutting, picking up, harvesting and heated and natural air drying was reviewed. Present and possible future harvesting practices were identified and discussed, with special emphasis placed on timeliness of operation, grain grade and quality, machine efficiency, energy requirements and economics. Research required to improve harvesting practices was identified.

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WINDROWING

This section contains information on the losses of wheat from the time the crop has reached maturity (35% m.c.) to the time the crop has passed into the threshing mechanism of the combine. Also included is information on the possible benefits of straight combining and leaving standing stubble.

Grain Losses

The losses encountered from the time the grain has reached maturity to the time the grain passes into the threshing mechanism of the combine can be divided into and discussed under the following headings.

Grade Losses: Grade losses are caused by adverse weather conditions and the possibility of a loss in grade occurring becomes greater, the longer the crop remains in the field. Research has shown that straight combining at high grain moisture content will advance the date of combining by several days over conventional windrowing or straight combining at lower grain moisture contents. Over a period from 1953 to 1965, the difference between the time the crop reached 35% m.c. and the time it reached 14% m.c. varied from 5 to 18 days according to Dodds (4). Dodds (6) has also shown that the 35% m.c. at which wheat is swathed may advance the harvest operations as much as nine days ahead of the stage of maturity (14% m.c.) usually acceptable as suitable for straight combining. It has also been shown by Dodds (6) that a crop which has been windrowed at 35% m.c. will take 4 days during normal harvest weather to dry to 14% m.c.

The weather conditions that most affect the grade of wheat are rain, snow and frost. Rainfall has been found to attribute the most to the gain in kernel moisture content, as found by Dodds and Pelton (7), and delays the day at which the grain can be combined under present practices. Relationships between rainfall, vapour pressure deficit and kernel moisture content have been determined by Dodds and Pelton (7) and have been used with average weather data from the past years to determine expected grade reductions up to the date of combining. Research on the affects of rainfall by Dodds and Pelton (7) has shown that windrowed grain loses moisture more rapidly than the standing crop. Unpublished research information has also indicated that during bad weather, the loss in bushel weight is greater in a windrowed crop than a standing crop and that more sprouting occurs in windrows than in a standing crop. Little research has been conducted on the effects of snow on the grades of wheat, but it can be assumed that once the snow has melted, it acts identical to an equivalent amount of rainfall. Frost significantly affects the grade of the wheat, especially at higher moisture contents. There is no research material available to determine the actual grade reduction that can be expected from frosts of varying severity nor is there information relating the grade reduction to the moisture content of the grain at the time of frost. Research is also not available to show whether the effects of frost are greater in the windrowed crop or the standing crop.

Reduction in grades or grade losses also occur if the grain is windrowed at high moisture contents, found by Dodds (6). Wheat may be cut at a kernel moisture content of 35% and allowed to mature in the swath without loss of quality or yield, as shown by Dodds (6). However, experience has indicated that straight combining of grain at high moisture contents (35%) and then drying, will produce a reduction in grade because of the large number of green kernels. The grade reduction is not due to a loss in bushel weight or protein content but only to the colour. Research to substantiate this information is presently not available.

Natural Losses: Natural losses occur in the field and are caused by environmental conditions such as wind, hail, and rain and by insects and animals.

Dodds (5) has shown that natural losses increase significantly as the moisture content of the grain decreases as shown in FIGURE 1. As the moisture content of wheat decreased from 35% to 14%, the natural loss increased from 16.8 kg/ha to 50.5 kg/ha. Natural losses are probably greater for standing crops than windrowed crops. However, information has not been obtained to determine the difference between the losses in standing and windrowed crop nor has information been obtained on how losses vary with wind speed, rain intensity or overall yield.

Mechanical Losses: Mechanical losses are the losses that occur during the gathering and processing of the crop. This section is concerned only with the mechanical losses that occur up to the time that the grain reaches the threshing mechanism of the combine.

Considerable research has been conducted by Dodds (4) to measure losses due to reel and cutterbars and to pickups for grain at various moisture contents. FIGURE 1 shows how the reel and cutterbar losses from windrowing or straight combining increase as the moisture content of the standing grain decreases. Pickup losses are shown to remain fairly constant regardless of the moisture content of the grain. Research has not been conducted to show how these mechanical losses are affected by crop yield or by ground speed.

Evaluation of pickups by AMA has shown that double windrowing of wheat can reduce pickup losses in a light crop by 1 bu/ac compared to single windrowing of wheat.

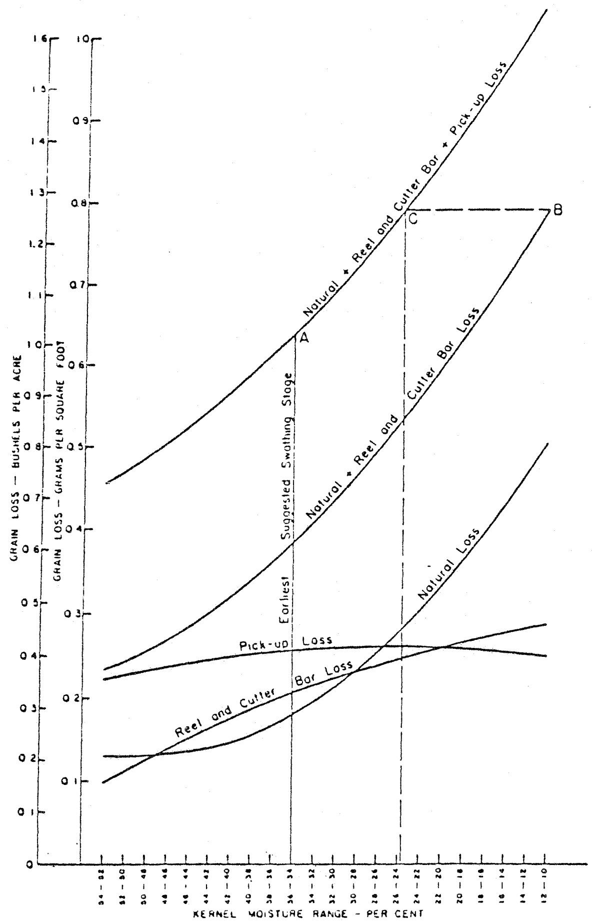

FIGURE 1. Natural and Mechanical Losses for Wheat.

Completion Losses: Completion losses are the losses that occur if the grain is left standing or left in the swath at the end of the year and are mainly caused by snowfall. Information of the first snowfall that remains for the winter is readily available from weather records.

Snow Retention: Straight combining of grain permits retention of the maximum height of stubble. Research has shown that stubble left standing during the winter, increases the amount of winter precipitation stored in the soil over the precipitation stored when the stubble is incorporated in the fall. Simka and Whitfield (20) showed that 80% of winter precipitation entered soil water storage each year when wheat stubble was allowed to stand during the winter. However with fall incorporation of crop residue, water storage efficiency equalled less than 25%. Also, Mathews (16) showed that any fall tillagae which incorporated the standing stubble reduced the yield of the succeeding crop.

Information is available to show the benefits of

Since capacity increases when the MOG/G ratio is decreased, straight combining will improve combine efficiency. Research is required to identify the amount of capacity increase by harvesting standing crop rather than windrowed crop.

Effect of Straw and Grain Moisture Content: A change in straw moisture content from 20% (very damp) to 6.5% (very dry) in Manitou wheat had little effect on straw walker efficiency over the moisture content range, as shown by Reed (19). However, the chaff load on the shoe increased a great deal as the straw became dry and broke up. Decreasing barley straw moisture content drastically reduced straw walker efficiency, according to Reed (19), and again increased shoe loading as straw breakup became excessive. It is likely that straw walker and shoe efficiency can be improved by harvesting at higher straw moisture contents, but this gain may be offset by the increased threshing difficulty at higher grain moisture content. Since capacity might be increased by harvesting at higher straw moisture contents, research is required for combine performance in windrowed and standing crop for the 10 to 30% straw moisture content range under Canadian prairie conditions.

Effect of Crop Type and Variety: The differences in combine capacity in different crops are well known, as documented by the Prairie Agricultural Machinery Institute (3). For example, combine performance in barley is significantly lower than in wheat due to increased separation difficulties. However, the differences in threshing can also be quite significant from variety to variety. For example, Neepawa wheat is much less prone to shatter than Sinton wheat, but is much more difficult to thresh. Since straight combining requires shatter-resistant varieties and in some areas sawfly resistant varieties, to reduce pre-harvest losses, straight combining appears to be at a disadvantage when harvesting crops prone to shattering or sawfly damage.

Effect of Climatic Conditions: The local climatic conditions and the geographical area have a large effect on the harvesting properties of crops, influencing such crop properties as straw break-up and threshability. Data gathered by the Prairie Agricultural Machinery Institute (3) for the reference combine shows a wide variation in combine capacity from year to year, even though grain and straw moisture content, crop type and variety and the MOG/G ratio were quite similar in the four years (FIGURE 4).

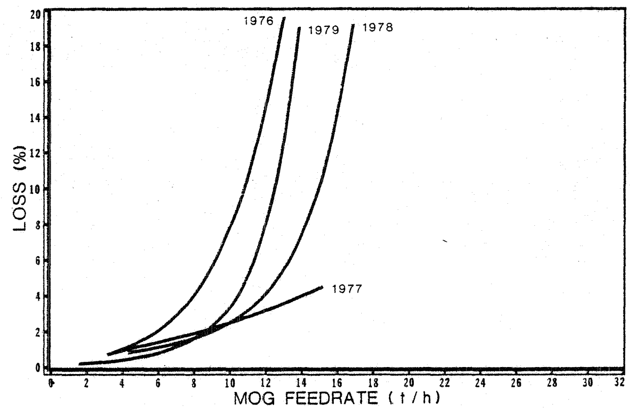

FIGURE 4. Total Grain Loss for the PAMI Reference Combine in Neepawa Wheat.

These results clearly show that research should preferably be conducted in different geographical areas or soil zones, and most important, over a number of successive years, before any conclusions are drawn.

Grain Quality

Grain quality, as affected by a combine, refers to the amount of damaged or cracked grain, and the amount of foreign material, or impurities, present in a sample of grain processed by a combine. Both cracked grain and foreign material are classed as dockage by the Canadian Grain Commission, for which a farmer receives a penalty. Grain tank dockage is mainly affected by combine adjustment, combine feedrate, straw and grain moisture content, crop type and variety and local climatic conditions during growth.

Effect of Combine Adjustment: Grain damage generally increases with an increase in cylinder speed and a decrease in concave clearance and feedrate, according to Arnold (2) and Vas and Harrison (22). Grain damage is usually compromised with cylinder loss, as one usually decreases at the expense of the other. Foreign material in the tank can be minimized by careful choice of forward speed and cylinder, concave and shoe adjustment, but many times reflects field conditions such as non-uniform maturity or weedy patches. For research purposes, optimum adjustments and uniform weed-free plots would be chosen to minimize the effects of these variables.

Effect of Straw and Grain Moisture Content: Low straw moisture content results in increased straw breakup and shoe loading with usually a resultant increase in foreign material in the tank. Grain moisture content had a mixed effect on grain damage in Park wheat, according to Harrison (13). Grain damage that was approximately 2% at 12% moisture content, decreased to about 1% at 16%, again increased to almost 1 1/2% at 18%, and decreased to 1/2% at 20%. Greater energy was required to break wetter kernels, except at 18% where the shear strength of the kernel increased, according to Zoerb and Holl (23), resulting in more damaged kernels. However, at 20% the kernels again deformed without exhibiting very visible fracture. Moreover, when the effects of damage and unthreshed grain were added together, the sum was largely independent of moisture content. More research is required to determine the effect of grain moisture content upon grain damage, particularly at moisture contents above 20%, as it appears that higher grain moisture contents will result in less damage and foreign material in the tank sample.

Crop Type and Variety: Certain crop conditions in wheat result in an increased number of whitecaps in the grain tank. Whitecaps can partially be reduced by adding filler blanks to the front of the concave. A crop such as barley is more sensitive to cracking and peeling than is wheat. An easy-threshing variety of wheat such as Sinton will likely crack less than a hard-threshing variety such as Neepawa as less energy is required to thresh Sinton.

Effect of Climatic Conditions: The effect of climatic conditions upon grain damage is largely unknown. It is reasonable to expect that the amount of stress a crop develops under and the number of wetting and drying cycles a crop undergoes will have an effect on its susceptibility to cracking. Further research is required in this area, especially over a range of grain moisture contents from 10 to 30%, and with repeated amounts of wetting and drying.

Power Requirements and Fuel Consumption

As energy costs increase, considerable attention must be devoted to the power required and the fuel consumed when harvesting. Research comparing fuel consumption and power requirements in standing and windrowed crops is required, with particular emphasis on fuel savings at different grain and straw yields and moisture contents in different areas and in different crops.

Straw Handling

The extra straw that must be processed when harvesting windrowed crop not only increases the power requirements of a combine, but increases the difficulty of evenly spreading the residue back on the field. When swath widths up to 12 metres are used, it becomes difficult to obtain a uniform distribution on the field. Non uniform spreading can cause problems in subsequent tillage and seeding operations, as well as affect the soil fertility levels. While several innovations have helped increase the spread of straw, some of these show increased power requirements. A benefit of harvesting standing crop would be reduced power requirements for chopping the straw, and more even straw distribution, as the major portion of the plant would be left intact.

Farming Practices

When windrowing, it is important to make the windrow at least as wide as conventional combine cylinders. If a narrow windrow is fed into a wide combine, only a portion of the combines threshing and separating capacity is used. When straight combining, correct adjustment of the table auger ensures a smooth uniform feed across the cylinder width.

An additional benefit of straight combining is the reduced ingestion of stones and soil, resulting in decreased damage and wear, especially in areas when crops are thinner and windrows rest on the ground.

The cost of owning and operating a combine is a major cost in cereal crop production. Self-propelled combines cost from $50,000 to $110,000 complete with pickup header. It is not surprising that farmers have gone to equivalent sized pull-type combines at approximately one-half the cost, and then purchased a tractor with the remainder of the cost difference. This poses an interesting challenge when considering straight combining, as header size is restricted to 5 metres, and the larger self-propelled combines require headers of up to 9 metres. This in itself may be a deterrent when considering straight combining as a farming practice.

New Concepts

Combine design has entered a new and exciting era, with several new threshing and separating concepts. The recent developments in combine design involve orientation of the threshing cylinder parallel to crop flow instead of perpendicular. Crop moves in a spiral pattern through the combine, resulting in more passes by the concaves, and more opportunity for grain separation with less grain damage. The net result is much higher capacity, especially in barley, and reduced grain losses. Again, these new concepts may also deter farmers considering straight combining, as in many areas of the province the larger combines may not be sufficiently loaded.

DRYING

This section describes the method of operation of natural air, heated air and multi-stage drying systems, and outlines the capabilities and advantages and disadvantages of each system. An economic analysis of the three systems of drying is presented.

Natural Air Drying

Method of Operation: Natural air drying consists of a fan pushing air into a bin through a perforated floor or a system of ducts, thereby removing moisture. The process consists of trying to push the drying front through the grain before spoilage occurs.

Advantages: Natural air drying is usually the cheapest way to dry. It requires the least amount of handling and labour, and usually results in the best grain quality.

Disadvantages: Natural air drying is very dependent on the weather. In some years, this system may not be capable of drying the grain. It requires very good management and constant observation, and since every situation is different, no direct rules apply. There is a tendency to overdry the bottom of the bin in order to bring the top of the bin to a safe moisture content. For cereal crops, the feasible upper moisture content limit is about 19 to 20% wet basis depending on the situation as shown by Friesen et al (11). A natural air drying installation will probably require modification to the farm electrical supply due to increased load. The cost of installation and also the larger supply rate will likely increase the farmer's electrical costs.

Heated Air Drying

Method of Drying: Heated air drying consists of forcing artificially heated air through a layer of moving or stationary grain. Drying is accomplished in a shorter time than natural air drying, usually taking only ten to fifteen minutes per percentage point of moisture removal. Heated air driers are usually sized to dry grain at the same rate it is harvested.

Advantages: Heated air drying allows cereal grains to be dried at moisture levels above the practical limits of natural air drying in almost any weather condition. No modification of farm electrical capacity is necessary as heated air driers can be powered by a tractor. Heated air driers also allow for the immediate sale or use of dry grain.

Disadvantages: Heated air drying is normally the most expensive method, and requires the most labour. The quick heating and cooling cycle increase the possibility of grain damage, especially as the grain approaches a dry condition.

Multi-Stage Drying

Method of Drying: Multi-stage drying involves drying grain in two separate processes. A heated air dryer removes an initial amount of moisture, and a natural air drying system removes the remainder, taking the grain down to the final desired moisture content. Multi-stage drying is normally associated with grain that requires a large amount of drying of at least five or more points of moisture removal.

A multi-stage drying system initially seems like an excessive capital expenditure, but may be quite feasible. Since many farms today now use large steel bins, aeration is a basic requirement. Natural air drying simply means purchasing a larger fan than if using aeration. Also, hot air driers become practical because natural air drying systems may not be adequate in extremely poor drying years, and do not provide for immediate sale of grain.

Depending on the moisture level the hot air drier will reduce the grain to, there are three main combinations of hot air and natural air drying, as discused by Friesen et all (11).

1) Combination drying - hot air dry to 20% m.c.
   - natural air dry to 14% m.c.
2) Dryeration - hot air dry to 16 - 17% m.c.
   - natural air dry to 14% m.c.
3) In-storage cooling - hot air dry to 15 - 16% m.c.
   - natural dry to 14% m.c.

Table 1 presents relative fuel consumptions, dryer capacities, drying energy, and energy used based on a percentage of heated air drying for four methods of drying corn from 25.5% to 15.5%. Note that combination drying is the most efficient, using only 53% of the energy required for heated air drying.

TABLE 1. Comparison of Relative Fuel Consumptions and Dryer Capacities for Various Drying Methods (Adopted from H. Cloud and R.V. Morey, Univ. of Minnesota).

METHOD	LITRES OF PROPANE PER TONNE OF CORN @ 5°C	kWh OF ELECTRICITY PER TONNE	RELATIVE DRYER CAPACITY	ENERGY TO DRY MJ/tonne	ENERGY % HEATED AIR DRYING
Heated Air Drying	30	4.0	1.0	721	100
In-Storage Cooling	26	3.2	1.35	623	86
Dryeration	22	2.8	1.6	527	73
Combination Drying	12	28.0	3.0	383	53

Corn Dried from 25.5% to 15.5%

Advantages: Multi-stage air drying has the flexibility of hot air drying, consumes less energy than hot air drying, and results in better quality grain than hot air drying.

Disadvantages: Multi-stage air drying require good management practices. The capital expense also appears high, although not readily apparent. For example, the required capacity of the heated air system and the natural air system will be less than if each system was the only drying device. However, based on available information, the actual values are difficult to estimate.

Drying Energy Consumption and Cost

A comparison of energy consumption and total costs using natural, heated and combination air drying is presented in TABLE 2. Several assumptions have been made, as outlined in TABLE 2, but costs are presented for drying wheat from 20% m.c. down to 14% m.c. Natural air drying showed a total cost of $6.30 per tonne, as compared to heated air drying at $12.12 per tonne and combination drying at $10.18 per tonne. This indicates that combination air drying, while involving more capital expenditure, is quite feasible. However, further research is required to clearly define which method is best to use. Combination drying is a new area in itself, and though research has been conducted using corn, in cereal grains many questions need answering. In particular, what is the cost and energy use? What drying temperatures are best, and what is the effect on quality? How much labour is required, and what is the correct size of equipment? These questions, and many others, require more research.

TABLE 2. Comparison of Energy and Cost Using Different Drying Methods.

	FIXED ($/tonne)	ENERGY ($/tonne)	TOTAL ($/tonne)	ENERGY (MJ/tonne/%pt)
Natural Air Dried*	5.81	.49	6.30	8.9
Hot Air Dried**	10.29	1.83	12.12	51.7
Combination Dried***	9.21	.97	10.18	27.4

* Energy and Cost for Natural Air Drying from 20% to 14% starting August 15.

1. Fraser et al, 1980, Cost Prediction for Drying Grain with ambient and solar heated air in Canada, Canadian Agricultural Engineering, June.

** Energy and Cost for Hot Air Drying from 20% to 14% in a continuous flow drier with ambient temperature at 15.5 C.

2. Grain Drying Costs, 1980, FBM Data Manual, Saskatchewan Agriculture, Regina.

*** a) Fixed Costs - assumed hot air drier cost is half since smaller capacity drier required for combination drying.
- assume natural air drying cost reduced by 30% since system does not have to be sized as large with a hot air drier as backup.

b) Energy - from TABLE 1 where predicted combination drying requires 53% of energy of hot air drying.

RESEARCH REQUIRED

It is recommended that the following research be conducted to obtain missing data that would complete a feasibility study on different harvesting systems:

1. Determining the natural, mechanical and completion losses, grade reduction, loss of bushel weight, loss of yield and loss of baking and milling quality of easy and hard threshing wheat for standing and windrowed grain between 14 and 35% m.c. in different locations under different weather conditions over four successive years.

2. Determining, in moisture deficient geographical areas, over successive years, the yield benefits obtained from increases in snow cover resulting from increased stubble height.

3. Obtaining comparative grain loss, capacity, power and fuel consumption data for conventional and rotary combines in windrowed and standing crop at various grain and straw moisture contents (14 to 35%) with easy and hard-to-thresh wheat varieties in different geographical areas over successive years.

4. Gathering data on the effects on crop yield and uniformity of maturity caused by non-uniform straw and chaff distribution, and determining the improvement, if any, resulting from increased stubble height when straight combining.

5. Comparing the performance and effect on grain grade and quality of three drying systems: heated, natural and combination air drying over a range of moisture contents for wheat. Particular emphasis should be placed on combination drying above 20% m.c.

6. Preparing an economic analysis of the following harvesting systems for the Brown, Dark Brown and Black soil zones:
   a) Windrowing 35%, harvesting 14%
   b) Windrowing 35%, harvesting 20%, natural air drying to 14%
   c) Windrowing 35%, harvesting 20%, hot air drying to 14%

d) Windrowing 35%, harvesting 25%, combination drying to 14%
e) Straight combining 35%, combination drying to 14%
f) Straight combining 30%, combination drying to 14%
g) Straight combining 25%, combination drying to 14%
h) Straight combining 25%, hot air drying to 14%
i) Straight combining 20%, hot air drying to 14%
j) Straight combining 20%, natural air drying to 14%
k) Straight combining at 14%

SUMMARY

Present farming practices currently involve windrowing when the crop reaches 35% m.c. and harvesting when the crop has natural field dried to 14% m.c. Farming practices are changing as more farmers have installed heated and natural air drying systems. Two alternate harvesting systems now seem feasible but require more research: 1) Windrowing at 35% m.c., harvesting at 20% m.c., natural air drying to 14% 2) Straight combining at 25% m.c., and combination drying to 14% m.c. Several other harvesting system combinations should be investigated to obtain a comprehensive overview of the energy costs and economics of operation.

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