RECENT ADVANCES IN HAY MAKING

M. W. CROSS, Massey University of Manawatu

Hay is an important crop to the New Zealand. farmer. Over 800,000 acres of lucerne and pasture are cut and conserved in this form each year compared with 180,000 acres for silage. Hay is pleasant to handle compared with silage, but requires more physical labour, as complete mechanisation from field to storage to stock has not advanced to the same degree. Also it is more vulnerable to the weather. As a result considerable effort and ingenuity have been applied to reduce both field losses and physical effort, either by endeavouring to mechanise completely present methods of conservation or by examining alternative forms.

Confusion has frequently arisen in the interpretation of some overseas trial results and recommendations through the lack of distinction between lucerne hay and pasture hay. Treatments advocated for hay (lucerne) when applied to hay (pasture) often fail to show any worth-while effect. Conversely substantial losses can be incurred by applying vigorous pasture hay treatments to lucerne hay. In this discussion the distinction is made where necessary.

Improving the Quality of Hay

The method of conservation of grass has no influence *per se* on the feeding value where each method is applied under ideal conditions. No method of conservation can produce a high quality product from poor quality material. Differences found in practice are usually. linked to the stage of maturity at cutting, to weather damage after cutting, or to storage conditions. Thus arises the variation in feeding value between artificially dried hay, silage, and field-cured hay. When hay is cut at the same time from the same pasture and given ideal treatments, artificial drying will produce the highest quality material because of the lower losses during making.[1]

The composition of a pasture will influence the quality of conserved herbage. Practices designed to promote vigorous growth of desirable species are essential-fertilising, drainage or irrigation, correct grazing management. The stage of cutting also determines quality and quantity. The optimum time of cutting strikes a balance between total dry matter, nutrient content, and digestibility so that an acceptable yield of a nutritious product is obtained.

This period is around the early flowering stage.[2,3] Dr D. J. Minson states, "It is now generally agreed that **earlier cutting is the most effective method for improving hay quality".**

The weather after cutting can make or mar a crop. If conditions are unfavourable it is better to delay cutting (and lose by reduced digestibility) in the hope of an improvement than to cut regardless of the weather and probably lose the whole crop. Meteorological forecasts should be used. Overall they have proved 75 per cent correct and are improving each year. Short-range forecasts of periods of fine weather are available for specific localities for the cost of a reply-paid telegram. A good knowledge of local cloud formations is invaluable and a combination of the two can take much of the guesswork out of the decision to cut or not to cut.

Once the hay is down, correct and timely use of suitable machinery will shorten the drying period and reduce losses.[4] Equipment varying in price from a few pounds for a simple attachment to a mower to many thousands for elaborate barn drying facilities or special packaging machinery is available. Not only is it necessary to select that which is most suitable from all aspects of price and performance for the property under consideration, but once purchased, equipment must be used to the best advantage within its capabilities and limitations. It is the purpose of this paper to discuss the more recent advances in hay making techniques which are of interest to New Zealand farmers.

Hay Wafers

Hay may be stored in many forms: loose, baled, wafered, chopped, ground, or pelleted. Interest has been aroused in the potential of wafering. Compressing hay into small packages (4 in. X 1½ in.) of greater density (24 - 30 lb/cu. ft.) than baled hay (10 - 12 lb/cu. ft.), opens the way to complete mechanical handling from field to storage to stock.[5] An added attraction is that less storage space is required. Feeding trials have shown definite though limited increases in weight gain of the order of 2.5 per cent in favour of wafered hay.[6] Wafering prevents sorting by the feeding animal, the material is less dusty than loose or baled hay, it withstands handling and prolonged storage,[7] and leaf loss at feeding time is virtually eliminated. As well it is in a desirable form for commercial trading and transport.

It is desirable to cut hay with a flail harvester, dry it to a safe storage moisture content (15 - 18 per cent moisture content (m.c.)), and then pick-up with a flail-type attachment on the wafering machine, which ensures thorough mixing of the swath.[8, 9]

A slight amount of water is added in the wafering chamber of one machine, but not with others. Lucerne and clover-grass mixtures with a high leaf: stem ratio are most desirable.

Mobile field-wafering machines have been produced and are. currently undergoing field evaluation. They seem to be working satisfactorily and have an output of 5 to 6 tons of wafers per hour.

Although the picture appears encouraging, there are many difficulties and disadvantages which may be hard, if not impossible, to overcome; thus the practice may never become an established farm method of conserving grass. The cost of the machine is high, £3,500 plus is suggested for one with an output of 5 tons per hour. An engine of 120 h.p. or more is needed, and wafer-forming pressures of around 4,500 pounds per square inch provide a real problem in the design of an economic unit because of a high wear rate.[10, 11] The major objection is an economic one. Hay is not a high-priced commodity and the increased operating and production costs of this form of packaging are likely to nullify any savings in other directions.

Artificial Drying of Baled Hay

The theoretical function of any system of hay making is to reduce the moisture content of the herbage to a safe storage level as quickly as possible and at the same time minimise losses. Artificial drying of baled hay offers three distinct benefits in that it reduces the time that hay is exposed to the weather, it reduces very considerably the leaf loss of clover and lucerne, and it allows out-of-season hay making.

In its most economic form artificial drying is used to extract only the last of the moisture from the crop. Full advantage should be taken of field drying treatments to reduce the moisture content to around 35 per cent to 40 per cent. This can be done in one to one and half days in good weather; thus the weather risk is virtually eliminated and curing losses are considerably reduced. At 35 per cent moisture content when the hay is baled the leaves are still tough and firmly attached to the stems. During forming and compression of the bale there is no cracking or fragmentation of the leaves as occurs with baling at field-dried levels. When the bales are fed out the absence of shattered leaves and their loss on the ground or with wind is most noticeable. Because the last 15 per cent of moisture is to be extracted artificially, immature material can be cut, even though it may be too early (or late) in the season for good field curing.

These advantages largely explain the' reason why barn-dried hay has been superior in feeding trials overseas to silage, haylage, and field-cured hay when cut from the same pasture at the same time and all given "ideal" treatment.[12, 13] Pilot trials in New Zealand by commercial and research organisations have clearly indicated that artificial drying has a place in this country.[14] Field experience has since demonstrated the practicability of drying early cuts of both lucerne and pasture hay and late cuts of red clover and ryegrass mixtures which would have been impossible to cure in the field. During the haymaking season artificial drying has produced higher quality hay, judged from the appearance of the baled material, than field curing. No feeding trials have been conducted.

With lucerne especially, which when cut at the correct stage (quarter bloom) consists of 57 per cent leaves, artificial drying will (because of leaf and colour retention) produce a much more valuable product than will field curing. The extra value, if the hay is sold, will more than offset the cost of drying.

Current research may establish improved methods of artificial drying,[15, 16] but in the meantime forced-air ventilation with unheated, warmed, or hot air is meeting with approval when used intelligently in localities where the climate is suitable.

Unheated air drying is generally confined to permanent drying barns where the hay, when once stacked over a ventilated floor, is left in storage. Electric fans are most convenient, but a power supply must be available at reasonable rates. Drying is slow, but as there is plenty of time to do it the fact that it may take up to a month to dry 20 to 25 tons of stored hay in a batch is not' a serious disadvantage. Moisture content at baling should not generally exceed 30 to 35 per cent, except during periods of high air temperature and low humidity, and air flows of 35 to 45 cu. ft./min per sq. ft. of floor area at 23 to 3 in. water gauge should be regarded as a minimum.[17]

Equipment and power costs increase as drying is speeded up, so it is sometimes economical to take as long in drying as possible without risking moulding or heating of the baled hay.[18] Supplemental heat can be applied conveniently by inserting heating elements in the air flow and these make this type of drier more versatile. It can then be used for out-of-season hay, but bale depth should not exceed 6 ft for 45 per cent m.c. material[19]

Warmed air drying (low temperature rise) can be used in a modified Dutch barn with a temporary ventilated floor and corrugated iron sides, or for drying tunnel stacks of bales either in the field or in a standard Dutch barn. Mobile drying units comprising a large-capacity fan (32,000 - 50,000 c.f.m. at 2 in. w.g.) driven from a tractor p.t.o. or by separate engine, draw the air over the power unit, thus utilising the waste heat of the motor to provide a temperature rise the equivalent of up to 4 kW of electricity. (The exhaust pipe discharges into the open air well above the air intake.) The temperature rise of this high volume of air is generally around 5 to 10 degrees, but during periods of high humidity it can be increased to 20 degrees by restricting the air flow with baffles.

These units are extremely versatile, and can dry in batches of up to 2,000 bales of 35 per cent m.c. hay, but are better used with 800 to 1,000 bales per batch, depending on the moisture content, which should not exceed about 45 per cent.[20] A typical turnaround time is about a week; during periods of low humidity shorter times are possible, and under humid conditions a fortnight may be required.

Hot air drying with portable units can be used to dry tunnel stacks, ventilated platform stacks, or wagon loads of baled hay. The unit is coupled by a flexible connecting tube to the tunnel, platform, or wagon, an electric fan supplies the air ventilation, and a fuel-oil burner (through a heat exchanger) raises the air temperature to about 160 degrees F. The high rise promotes rapid drying—up to 2 per cent m.c. reduction per hour-and is suited to smaller batches, which can be dried overnight. A "hay in a day" system based on this drier has been evolved. Lucerne cut and crushed early in the morning and turned at intervals during the day is baled and loaded on to wagons in the late afternoon and artificially dried overnight ready for storing next morning. On suitable days top quality hay in batches of about 100 or more bales can be guaranteed. It is hoped to obtain field experience with this drier during the 1963-64 season using a power take-off driven model.

Heating greatly increases the moisture carrying capacity of the ventilating air and though this greatly increases the drying cost, there are occasions when 'it is fully justified. Nevertheless as it is cheaper to move air than to heat it, the low-temperature-rise driers mentioned earlier, which move large quantities of air, appear the most suitable at the moment for general application.

For successful operation of all methods of artificial drying certain ancillary equipment is needed. A simple U-tube manometer fitted to the blower will register back pressure and protect the' motor from overload. A long-stemmed type hair hygrometer placed in the air stream will indicate the humidity of the ventilating air and show at a glance the need or otherwise for additional heat. The temperature rise employed can be checked by two thermometers, one for the ambient air, and one for the ventilating air, It would be desirable to have some simple means of checking the moisture content of the baled hay. At present the hair hygrometer is being used with varying success, but more critical research is needed to establish its efficacy and a reliable method of use. Bale weight should not exceed about 70 lb for 35 per cent m.c. hay (less for moister hay), which dries down to about 56 lb, making a convenient weight bale for handling and one which is still durable.

Many investigations have been made overseas into the economics of artificial drying and costs for the various methods are available.[13, 19, 20] In all cases results indicate the practicability of the methods used. New Zealand experience suggests that the **total** cost for warm-air drying is likely to be around 30s. per ton of dried hay. This seems a small "insurance premium" for quality hay.

The real advantage of artificial drying lies in its ability to deal with hay cut at an early stage of maturity, when its nutritive value is high and the weather is unsuitable for field drying.[21] Whether the New Zealand farmer will accept the increased cost depends on the value placed on the hay. If hay is required for roughage and maintenance, field curing will suffice. If it is used to replace silage and crops as a production ration, artificially dried hay of top quality can be most profitable. The main interest at the moment is in drying the more valuable lucerne, but good quality ryegrass-clover pastures can be equally valuable.

Field Working Hay

Dr Minson[2] states that "earlier cutting is the most effective method of improving hay quality". This could well be amended to "earlier cutting and more efficient use of hay-making equipment already on the farm is the cheapest and most effective method of improving hay quality".

A swath which has been left as it falls from the mower knife may be partially protected from mist and very light rain, but. any advantage gained is more than offset by the slow and uneven drying which results. Hay made in this fashion will often take seven or more days to dry, even in summer. During periods of high humidity or when the soil is damp, drying may be impracticable. Tedding or turning, combined with moving the swath on to fresh stubble, leads to more rapid and even drying, while laceration, bruising, or other mechanical treatment will further hasten the removal of moisture from young lucerne and pasture herbage.[22]

Probably the most important step forward in field-working equipment was the introduction of the **finger-wheel rake. No** gearing or transmission, the minimum of moving parts, very low maintenance, and a high rate of work make it an ideal tool for haying operations. It has its limitations, but these are not as great as many critics claim. It is very gentle with the crop, yet can invert and loosen a swath satisfactorily. Rolling or roping when swath-turning can be avoided by hitting the main part of the swath with the last reel only and travelling at at least 6 m.p.h., preferably more. This turns the swath 180 degrees and if speed is sufficient and the angle of the finger-wheels correct, will spread it 3 to 4 feet wide. The high rate of work gives quick coverage of the field and allows the "constant turning" technique to be fully employed. With conventional rakes the same comments apply; use only as much of the reel as is necessary to turn the swath 180 degrees. The old reel-type rakes with the removable centre sections are ideal in that only the minimum number of tines was left to allow two separate rows to be turned at once without roping. Their speed is slow, 4 to 43 m.p.h., but there is no reason why they cannot be kept working in the field all day.

The principles of forming windrows as advocated by literature accompanying American-designed machines is wrong when applied to general haymaking in most of the North Island and the humid areas of the South Island. Almost invariably emphasis is placed on rolling the mower swath into a hollow cylinder. (If these rakes are used with their full width, they can perform this operation well.) This 'is excellent for the final windrowing before baling, but for turning hay only the last portion of the reel should be used; just sufficient to turn the swath 180 degrees. Hay should be moved frequently-the more often and more vigorously the better in the early stages of drying. More gentle treatment is needed when the moisture content reaches 30 per cent or lower, especially with lucerne and clover hay.

The importance of soil moisture in retarding the drying of hay is considerable.= Lucerne cut with a mower, very severely crushed, and placed on black polythene dried to 20 per cent moisture in 4 hours while comparable material placed on the stubble took 25 hours to reach the same figure. Lucerne cut with a mower and placed on the polythene dried in 50 hours, but on the ground was not dry after 72 hours. In no case was it turned after cutting. To duplicate this result in practice, turn the hay on to fresh ground as often as possible. In our own trials with pasture hay that cut with a flail harvester and turned frequently was fit for baling within 24 hours while that cut with a mower and turned frequently (2 hourly) was ready within 48 hours.[24]

Farmers are prepared to grind around all day tilling a dusty cultivated field; how much more pleasant to drive around a clean, fresh hay paddock, especially when the results of frequent turning have such a pronounced effect in reducing drying time and maintaining quality. Perhaps such a radical departure from the old system is too much to expect, but even if the swath is turned once (immediately after mowing) drying time would be reduced by a day. This technique is not new, it was advocated in 1938.[25]

Comparative -newcomers to the haymaking field are the **swath** aerators-variously called "fluffers", "wufflers", "conditioners", "tedders", etc. They are designed to lift and loosen the swath vigorously and deposit it on a fresh piece of ground in a fluffy windrow. For pasture hay this seems the best investment if another implement is to be purchased, and for large areas well warranted. Recent models are versatile. They can handle two 5 ft swaths at a time, leaving them in single rows on fresh ground or doubled ready for baling. In the early stages of drying they should be used as frequently as possible. With some a more gentle action can be obtained for use in the final stages to minimise leaf loss on susceptible crops. Most are driven from the tractor p.t.o., and the speed of the rotor and design of the exit should be such that the crop is not flung on to the ground but allowed to fall gently, thus keeping it open and loose. Rear-mounted tines can be most useful in absorbing the velocity of the hay before it lands on the stubble and deflecting it on to new ground.

Whatever swath treatment is used, whether side rake, aerator, crusher, crimper, or flail harvester, it should be commenced immediately after mowing, the implement preferably being attached in tandem to the mowing tractor as are a number of models. In all research reports where field working has been studied, mention is made of the need to commence immediately after mowing. Even where no more turning is done for two or three days, the first turn should follow the mower as soon as possible.[4,20,21,25,26,27] Bruhn[28] states: "Delaying crushing following cutting causes no harm but the loss of a higher drying rate compared with the cut/crush technique".

Crushing and ***crimping*** have undergone considerable scrutiny in recent years. For lucerne the effect can be summarised thus: "The better the weather the better is the effect of crushing or crimping". As drying conditions deteriorate so does the benefit of cracking the stems diminish until the stage is reached where, if rain occurs, the crop may suffer more loss if crushed than uncrushed. Crimping, especially with square-edged teeth on the crimping rolls, produces more clipping of leaves and stem tips (and consequent higher losses) than crushing with smooth rollers,

A comparison of the drying rate between types of crushing equipment is really a comparison of the degree of crushing; the more severe it is the quicker the material dries. This must, for practical considerations, be balanced against the increased field losses with very severe crushing. Young lucerne (at quarter bloom) benefits more from crushing than more mature material with respect to hastening the loss of moisture. Boyd[29] reports 'that conditioning (crushing) can reduce drying time by about 30 per cent, reduces weather damage because of the shorter time the crop is exposed to the weather, and reduces **overall** field losses due to shattering because of the more -uniform drying rate of leaf and stem and because curing is quicker. It also conserves colour and feed value through shorter exposure and less shattering, thus producing a higher quality product with increased market value.

In another series of trials"* both the physical losses in the field and the total loss during making, in fine weather, were highest for crimped material (4.6 per cent of total yield), lower for crushing with rollers (2.1 per cent), and lowest for mown only (1 per cent). Feeding trials, using sheep, with this material showed no consistent advantages for any treatment. It seems fairly conclusive that crushing or crimping confers no benefits other than a shorter time for lucerne to reach a safe baling moisture content, and this may result in slightly higher losses compared with mown only cured in **fine** weather with **rapid** drying conditions.

With grass-clover hay the effect of crushing or crimping is less marked. If severely crushed, immature pasture will dry more rapidly in the early stages only. As drying progresses the rate of moisture loss is no greater than in uncrushed material. If crushing is not severe, the overall result is little if any better than aerating.[4] Crushed or crimped grass still takes a comparatively long time to dry unless it is frequently turned or aerated; hence the risk of rain damage is still high. Whatever the material that is crushed it will then suffer greater nutrient losses than aerated material.

Aerating or tedding with a vigorous-acting machine which leaves the hay in a fluffy windrow on a fresh piece of ground (used immediately behind the mower and frequently thereafter) is the best treatment for general conditions. If rain is imminent, the swath should be fluffed up, and this should likewise be done immediately after rain. The hay will suffer less in this way than if left untouched in the mower swath.[4]

The flail-type forage harvester makes "hay-in-a-day" possible when chopping is followed by frequent turning, but there are many disadvantages which make the method unsuitable for general recommendation. All trials are in 'agreement in this regard.[24,27,31] For best results it has been recommended that the rotor speed should be reduced from 1,500 r.p.m. to 1,000 r.p.m. (6,000 ft/min tip speed) and a forward speed of 4 m.p.h. maintained. Because of variations in flail design, some harvesters can cut satisfactorily at a lower rotor speed; hence the recommendation could well read "run the rotor as slow as is consistent with satisfactory cutting and maintain as high a forward speed as the power unit will permit". Because of the lacerating effect of the flail, high rotor speeds induce high losses of short material left by the pick-up baler.[32] Some flail type harvesters are being fitted with powerful engines (up to 100 h.p.) and when used for cutting hay can be towed at a high forward speed. This type of unit is very satisfactory.

Some device is needed to absorb the velocity of the hay as it is discharged from the flail; otherwise the windrow should be loosened or turned immediately. Hay directly from a flail is packed on to the ground, air movement through the swath is restricted, and overdrying of the surface occurs.

In general it is better to cut with a mower and use the flail to ted the crop immediately afterward. This should be followed by tedding or turning with conventional equipment as often as is necessary to prevent overdrying of the surface and to keep the swath loosened and-on dry ground. Tedding with a flail causes little chopping or cutting, but does give a measure of bruising and lacerating. It should be done only once.

Swathers are being used increasingly for haymaking. Currently, the self-propelled swather with a 10 to 16 ft cut is being featured and is usually fitted with a smooth-roller crusher. This implement, originating in the United States of America and quite widely used for windrowing cereal crops, has been found suitable for lucerne in particular. The main objective is to cut the crop faster so that it all dries equally during the day it is cut. In arid areas and light crops, the practice of cutting a wide swath, crushing and windrowing in one operation makes sense. The fluffy windrow placed on dry soil will lose moisture rapidly and in some instances needs only one turning. In humid areas and heavy crops the recommendation is to take a narrower cut and team-up with some form of artificial drying. As field drying will not be lower than 35 to 40 per cent m.c. in this case the windrow will accept vigorous aerating without harm, Alternative uses include cutting of silage for wilting (before being picked up with a chopper or flail harvester), and windrowing cereals and a variety of other seed crops (without the crusher).

Obviously swathers are more suited to large acreages and flat or smooth land, where the high speed of up to 8 m.p.h. can be utilised to the full. Performance in heavy or tangled crops is surprisingly good, relative freedom from blockages being assured by the special pick-up reel which sweeps the crop off the cutter bar.

Swathers are not uncommon where lucerne is harvested in the driers areas of the South Island, Because of their price and wide cut they are likely to be restricted to localised areas in the North Island where excellent drying conditions can be expected during the hay making season.

Cutting

By 1865 the conventional reciprocating mower had virtually assumed its modern form and improvements since then have been in matters of detail rather than changes in the basic concept.[34] It is surprising that this fundamentally inefficient cutting principle has persisted for so long. Perhaps the next 100 years will produce a device which is more efficient, but it must be at least as effective as the present mower to receive farmer acceptance. Current mowers are vastly changed in performance compared with their horse-drawn counterparts. Side or rear-mounted models can be attached to the tractor quickly and effortlessly. Cutting widths have increased up to 10 ft,[35] mowing speed has increased to 10 m.p.h., and cutter-bar vibration has, in some models, been almost eliminated. Of special interest is the development of the double-knife mower, in which the fingerless cutter-bar is fitted with two counter-reciprocating knives mounted back to back. During trials it has performed well, its particular advantages being (1) an almost complete absence of blockages in wet and dense crops and when the back swath is being cut, and (2) its ability to work without jamming on stony ground.[36] The specially hardened knife sections take rather a long time to sharpen, but can cut over 20 acres without change. An investigation into the behaviour of the crop during mowing advances the reason for the high speed of up to 10 m.p.h. during cutting.[37]

The rotary principle has been considered as a means for cutting hay, but no machine has been successful in capturing the market. Some designed for grass cutting have been used in isolated instances for hay, with apparently successful results. A current rotary slasher is offered for hay making and its performance will be watched with interest this season. The idea has much to commend it. There is no rechopping, the grass being discharged as cut in a loose swath, but some bruising, which should aid drying, results. Long skids on either side reduce scalping to a minimum if ridges are crossed at an angle. Cutting a 5 ft swath at 6 m.p.h. does not appear to absorb as much power, compared with most rotary slashers which rechop, and the absence of blockages is gratifying, except when cutting a flattened crop.

Probably the. ideal attachment to a mower for pasture hay would be a device which completely inverted the swath as it was cut, so that the butts were up and the leaves down. Perhaps this is impossible to devise, but an inexpensive arrangement of oscillating tines fitted to the back of the mower frame and actuated by the mower drive is being marketed and warrants further investigation.

Baling and Bale Handling

Though not new, the "roll-up" or round baler deserves mention because of the weather resistant qualities of the bales. This feature relieves the farmer working single handed with his own baler of the urgent need to collect and store bales safe from weather risks. Even if it rains, round bales will come to little harm in the field. Once the correct technique of forming a windrow has been learnt, and if a tractor with a live p.t.o. is used, most of the criticisms of this baler are nullified.

Self-propelled rectangular balers are now available, but these seem to be an economic proposition only for a contractor with a long season.

With the availability of tractors with live p.t.o.'s, the p.t.o. baler is becoming more popular and some are available with a 2-universal-joint drive shaft, which permits the elimination of any fluctuation of the drive to the baler on turns.[38]

In view of the need to handle field-dried hay gently, especially lucerne, to minimise leaf loss, it is difficult to reconcile the trend to the large-diameter pickups on current balers. With these the hay is hit by rows of single spring tines and lifted vertically almost 2 ft before being passed to the bale-chamber feed. It is logical to expect increased loss of leaves and short stems as the windrow is opened and lifted. Some of the older balers were fitted with very gentle lifting mechanisms-small-diameter pickups or draper-type canvas elevators. The pickup on the round baler is a typical example of those which cause minimum losses.

Bale-thrower attachments offer a considerable reduction in labour to the farmer who is prepared to modify his methods of carting and storage. Bales are made slightly shorter 'than standard and are tossed from the baler into a towed wagon. Controls are available to govern the length and, direction of throw. The wagon, when full, is towed to the barn, where an elevator (either angled or vertical) carries the bales to the roof and an adjustable sweep-arm deflects them to fall in the desired area. Random storage, such as this, leaves adequate ventilation yet occupies only 10 per cent more storage space.

This system is undoubtedly designed for stall or platform feed-

G8

ing where minimum labour is available and can be used to deliver hay to feeding troughs or racks. With the increase of platform feeding in this country, consideration of this system, or variations of it, is justified.

Another technique of mechanical bale handling requiring only one man is an automatic loader and stacker. The vehicle is available in either self-propelled or tractor-trailed form, is driven along the rows of bales, picks them up, and stacks them on the deck. When a load of about 50 bales has been collected the outfit is driven to the stacking area and the bales are mechanically transferred in one package to a compactly built stack which can be built up to 12 ft high. This system would be of value to the farmer who still stacks in the open. The stacks are very stable and when adequately thatched or covered suffer little from weather damage.

Although the front-end loader with a sweep or the self-energised bale handler developed at Lincoln College is quite often used, the combination of front-end loader and rear-mounted buckrake is not so common. The bales are left in heaps which fit the loader and buckrake by a bale sledge, are picked up front and rear by the tractor, and transported to the stacking area, the loader being used to lift them into position on the stack. Fast collection is both possible and cheap, physical effort is considerably reduced, and the method lends itself to making tunnel stacks for artificial drying. Another variation of this method which handles the bales in $\frac{1}{2}$-ton packages takes virtually all the effort from this part of the operation.[39]

Bale size is the subject of well merited criticism. Presumably because the charge for contract baling is per bale, farmers are loath to accept small or lightweight bales; the reverse is generally true-the bigger the bale the better. If the charge were changed to a per-ton basis, everyone would be better suited. A study of the physical effort involved during bale handling reveals that for the same total tonnage moved, smaller bales (45 lb) require less energy for stacking above 15 in high than heavy bales (65 lb).[40] (These "heavy" bales would probably be considered light by our standards.)

When bales are moved horizontally 14 times the tonnage can be shifted for the same energy by dragging compared with lifting and carrying.

Lighter bales than are normally made are desirable for artificial drying; with hay of about 35 per cent m.c. they should be not more than 65 to 70 lb. These would dry out to about 52 to 58 lb -still heavy enough to manhandle. For handling by bale throwers, bale loaders, automatic pickups and elevator conveyors light bales are desirable. This machinery will last longer in moving more light bales than fewer heavy ones. If machinery responds to this treatment, surely the human frame will do likewise.

Conclusions

Until recent years hay has been notorious for the amount of physical labour required to make and handle it. An early 18th century picture shows 122 people in the one field. Admittedly the number includes a troupe of morris dancers, musicians and others dispensing refreshments, but the majority were employed on the hay. (Five quarts of cider per day per man was an allowance in Worcestershire.)

Even today hay handling is still hot and thirsty work. Haymaking suffers from the lack of complete and integrated mechanisation possible with silage making. Much of our current equipment has been designed only to reduce the effort in certain sections of the work. For example, although a bale loader lifts the bales from the ground to a truck deck, they then have to be manhandled into position,

Investigations of the susceptibility of clover and lucerne varieties to mechanical damage indicate the desirability of considering fragility in future programmes concerned with selection and breeding for overall improvement of agronomic properties.[41]. A basic study of the mode of moisture loss from lucerne led to the establishment of a "hay-in-a-day" system and indicated the air velocity required for moisture removal.[42] Other processes have been developed which promote quick drying, minimum losses, and protection from the weather risk. Only relatively recently has attention been focussed on the complete mechanical handling of the forage (in various forms) from the field into storage. Interest is now being taken in the automation of live-stock feeding, and studies indicate a lower cost for such an installation as compared with pushbutton mechanised systems.[43]

When the whole process from growing the forage to utilising it in a dried form is considered as one operation, then and then only will it be possible to produce the ideal mechanised system.

The majority of this research emanates from overseas, where agricultural conditions are somewhat different from our own. But our pattern of farming is changing, We must keep an open mind and not be tardy in profiting from these new methods or variations of them which suit our requirements. Only by changing our methods to suit the machine, instead of expecting the machine to duplicate manual methods, will the full potential of mechanisation be exploited.

References

1 Carter, W. R. B., 1960: "A Review of Nutrient Losses and Efficiency of Conserving Herbage as Silage, Barn-dried Hay, and Field Cured Hay". J. Br. Grass. Soc.; 15 (3), 220.

2 Minson, D. J., 1963: "Conserved Pasture-Quantities and Quality". Massey Coll. Dairyf. Ann. 1963.

3 Oliver, J. H., 1960: "Quality Control in Haymaking". Agric. Engng. 41, (11), 748.

4 Mitchell, F. S., Shepperson, G., 1955: "The Effect of Mechanical Treatment on the Drying Rate of Hay in a Swath". J. Inst. Br. Agric. Engs.: 11, (3), 3.

5 Dobie, J. B., 1961: "Materials Handling Systems for Hay Wafers". Agric. Engng. 42, 692.

6 Bruhn, H. D., 1957: "Engineering Problems in Pelletised Feeds". Agric. Engng. 38, (7), 522.

7 Report to Readers, 1960: "Hay Wafers and Pellets". Agric. Engng. 44, (2), 60.

8 Lundell, V. J., Hull, D. O., 1961: "Field Production of Hay Wafers". Agric. Engng. 42, 412.

9 Huang, B. K., Yoerger, R. R., 1961: "Maceration as Pre-treatment in Hay Wafering". Agric. Engng. 42 Trans. ASAE 4 (1) GT69.

10 Shepperson, G., Grundy, J. K., 1962: "Experiments in the Production of Hay Wafers". J. Agric. Engng. Res. 7, (2), 105.

11 Dobie, J. B., 1960: "Production of Hay Wafers". Agric. Engng., 41, (6), 366.

12 Culpin, S., 1962: "The Feeding Value of Silage and Barn-dried Hay". J. Brit. Grass Soc. 17, (2), 138.

13 Thompson, J. M., Hall, J. K. S., 1962: "Barn Hay Drying at Auchincruive". West of Scotland Agr. Coll., Res. Bull. 30.

14 Cross, M. W., 1962: "Artificial Hay Drying". Massey Coll. Dairyf. Ann. 1962, 31.

15 Person, N. K., Sorenson, J. W., 1962: "Drying Hay with Infra-Red Radiation". Agric. Engng. 43, 204.

16 Hassler, F. J., 1959: "Theoretical Identification of a Critical Temperature-Moisture Relation in Foliar Drying". Trans. A.S.A.E. 2, (1), 48.

17 Shepperson, G., 1958: "Artificial Drying of Baled Hay-l. Rates of Flow and Static Pressure". J. Agric. Engng. Res. 3, (2), 153, and 3, (3), 214.

18 Hukill, W. V., 1963: "Grain Storage and Drying". Agric. Enging. 44, (7), 372.

19 Culpin, C., 1962: "Developments in Methods of Barn Drying". J. Brit. Grass. Soc. 17, (2), 150.

20 Hearle, W. L., Patterson, H., 1961: "The Design and Operation of Barn Hay Drying Systems with Special Reference to Drying in the Bale". J. Inst. Agric. Engs. 17, (2) 39.

21 Shepperson, G., 1960: "Effect of Time of Cutting and Method of Making on the Feed Value of Hay". Proc. 8th Int. Grass. Cong. 1960, 12B/4.

22 Shepperson, G., 1955: "The Effect of Bruising and Crushing on the Drying Rate of Grass and Lucerne". Nat. Jnst. Agric. Engng. Rept. No. 52.

23 Pederson, T. T., Buchele, W. F., 1960: "Hay in a Day Harvesting". Agric. Engng. 41, (3), 172.

24 Cross, M. W., 1960: "Greater Efficiency in Haymaking". Massey Coll. Sheepf. Ann. 1960, 199.

25 Cashmore, W. H., Denham, H. J., 1938: "The Drying of Hay in the Swath and Windrow". J. Minist. Agric. 45, 211.
26 Bruhn, H. D., 1955: "Status of Hay Crusher Development", Agric. Engng. 36, (3), 165).
27 Klinner. W. E.. 1961: "A Trial to Determine the Hav Yields Obtained by Using Conventional Hay Making Machinery and-Flail-type Forage Harvesters". J. Agric. Engng. Res. 6, (4), 315.
28 Bruhn, H. D., 1959: "Performance of Forage Conditioning Equipment". Agric. Engng. 40, (11), 667.
29 Boyd, M. M., 1959: "Hay Conditioning Methods Compared". Agric. Engng. 40, (11), 664).
30 Kepner, R. A.. Goss. J. R.. Mever. J. H.. Jones. L. G..,1960: "Evaluation of Hay Conditioning Effects".. Agric. Engng. 41, (5), 299.
31 Shepperson, G., Grundy, J. K., 1962: "Recent Developments in Quick Haymaking Techniques". J. Brit. Grass. Soc. 17, (2), 41.
32 Greenhill, W. L., 1961: "A Comparative Measure of the Mechanical Breakdown of Pasture Material by Flail-type Forage Harvesters". J. Agric. Engng. Res. 6, (1), 27.
33 Cross, M. W., 1960: "Haymaking with the Flail Harvester". Massey Coll. Dairyf. Ann. 1960, 145.
34 Cashmore, W. H., Newman, J. E., 1933: "The Development of Haymaking Machinery". Emp. J. Exp. Agric. 1, (1), 58.
35 Harbage, R. P.;, Morr., R. V., 1962: "Development and Design of a 10 ft Mower". Agric. Engng. 43, (4).
36 Nat. Inst. Agric. Engng. Test Rep. 335, 1963: "Busatis BM 315 kW Rear-mounted Double-Knife Mower".
37 Johnston, R. C. R., 1959: "Crop Behaviour during Mowing". J. Agric. Engng. Res. 4 (3) 193.
38 Cross, M. W., 1960: "The Arrangement of Power-take-off Drives on Farm Tractors". Massey Coll. Dairyf. Ann. 1960, 103.
39 Gustafson, M. L., 1963: "A New Bale Handling System". Agric. Engng. 44, (1), 14.
40 Hodges, T. O., Esmay, M. L., 1960: "Human Energy Expended in Handling Baled Hay and Straw". Agric. Engng. 41, (8), 502.
41 Shepherd, W., 1961: "The Susceptibility of Hay Species to Mechanical Damage". Aust. J. Agric. Res. 12, (5), 783.
42 Pedersen, T. T., Buchele, W. F., 1960: "The Drying Rate of Alfalfa Hay". Agric. Engng. 41, (2), 86.
43 Paine, M. D., 1963: "Control System Design for Livestock Feeding". Agric. Engng. 44, (2), 72.

DISCUSSION

Q. Have you any comparative data on the different methods and systems of haymaking in New Zealand?

A. Trials involving the use of different machines and systems have not been as extensive in New Zealand as overseas, but results from such trials as have been carried out, follow the same pattern as most of the overseas work.

Q. What sort of machine is considered most efficient for a man in this area who is making his own hay?

A. Cut the hay in blocks of up to 5 - 6 acres, start turning immediately, and keep on turning every two hours, or more frequently, until the crop is fit for baling. Use whatever rake is available-reel, fingerwheel, or aerator-treat the hay vigorously in the early stages to keep the swath fluffed up, but avoid turning the swath more than 180 deg.. each time. The better the drying conditions, the more frequently the hay should be turned.

Q. Would Mr Cross comment on the use of a flail harvester after cutting with a mower?

A. The flail can be used to aerate and partially lacerate a mown swath to reduce drying time but it should be done once only, as soon as possible after mowing. Subsequent turnings are done with, a rake. Overall, this is probably a better method than cutting with the flail as less chopping occurs and physical losses are reduced. However, drying time will be shorter if the hay is cut with the flail and turned frequently with a rake.