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# Comparison of methods for determining shatter losses in hay harvesting

Mechanisation in forage harvesting leads to shatter losses. Even under most favourable conditions 15 to 20 % of the yield remain behind on the field. Under unfavourable conditions up to 60 % of the protein originally present can be lost. Since the early 1970s the problem has been recognised by farmers and researchers. It was found at an early stage that considerable shatter loss particularly occurred with herbs rich in protein. The various methods employed to determine losses during 40 years of research have contained system related measurement errors. An approach shatter losses developed in 2009 by Agroscope Reckenholz-Tänikon Research Station ART was tested in collaboration with Kassel University.

## Keywords

Shatter losses, forage harvesting, windrow inverter, artificial stubbles

## Abstract

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When it comes to hay processing, four to five processing stages are necessary for the turning and windrowing operations, depending on the weather and the crop yield. Each process triggers mechanical losses as a consequence of leaves or parts of leaves dropping to the ground and these are known as shatter losses. The introduction of mechanisation has been accompanied not only by efforts aimed at reducing the workload, but also at diminishing the loss factor [1; 2]. Based on current state-of-the art knowledge, at least 15–20 % of the yield will remain lying on the field following completion of the full harvesting process. Herbs containing protein are particularly inclined to shatter losses [3].

## Calculating Losses by Weighing

Höhn [4] employed a “Differential Method“ based on weighing the forage yield derived from experimental plots of land after each individual processing stage (figure 1). The weighing operation itself, however, represents an additional processing stage which may in fact generate further losses because, to enable it proceed, the fodder has to be heaped into a pile, weighed and then re-distributed so that it can continue to dry out. In addition, this method of sampling is very demanding in terms of time and is also labour-intensive.

## Vacuuming Off Losses

Beckhoff et al. [5] opted for a different approach. The shatter losses were determined by means of a vacuuming-off operation over defined test areas. Vacuuming up may be carried out either on a single-point basis (approx. 1 sq. m.) or to encompass a more extensive area. Single-point sampling is frequently termed “the vacuum cleaner method“. Corresponding to the item of equipment used, sampling over an extended area is often described as the “leaf vacuum method” (figure 2).

Trials carried out independently by ART indicated that the losses are not evenly distributed on the surface but instead increase towards the centre of the windrow. This is a factor that needs to be taken into account when selecting the locations for the sampling exercise. As regards the leaf vacuum method, it can be helpful to carry out sampling crosswise to the direction of windrowing so that the test stretch takes up one to two working widths of the windrow inverter. Ahmels [6] pointed out

Fig. 1



*The difference method is very labour intensive*



Fig. 2

The vacuum method counts organic plant remains, e.g. organic fertilizer, as losses (Photo: Sauter)

that not only shatter losses but also other organic material e.g. slurry residue, dead plant components and small parts generated by multiple cutting operations may be incorporated as a result of the vacuuming action.

Even the two-phase vacuuming operation is not totally error-free. In this variant, selected strips are cleared immediately after mowing, marked and vacuumed off and then covered with the crop once more. The second phase serves to determine the shatter losses. However, dead components that have in the meantime become detached from the plants are also recorded here. Independent observations on the part of ART have shown that, in the case of long stubble or if a sampling exercise is conducted after a shower of rain, not all the shatter material from the plant will be vacuumed up. In the same way, dense grass cover from natural meadows makes it more difficult to collect the entire complement of loss residue.

Despite all the difficulties, the leaf vacuum method has developed into the norm where the calculation of shatter losses is concerned. There are numerous system comparisons based on this [7–12].

### Measurements under Standardised Conditions

In order to exclude unknown influencing factors wherever possible, approaches which would enable the losses to be recorded under standardised conditions were identified at an early stage. Ahmels [6], for instance, ensured that he had a firm foundation for his investigations. The crop was manually loaded on to a vehicle, formed into a windrow on an asphalted surface and subsequently processed in accordance with the approach specified for the test before being loaded up, either by hand or by means of a pick-up. However, this procedure failed to answer the question of the extent to which the measured values were distorted due to the absence of the stubbles that facilitate the work of the inverter tines and the pick-up on the field. Ahmels also managed to establish that, as regards the salvage operation and depending on whether a pick-up was used or a hand rake, different rates of loss would be recorded.

Manns [13] devised a test bench which he presented in conjunction with Hensel [14]. The central elements of this test bench are grilles fabricated from expanded metal together with a rotating, speed-regulated disk on which the tools comprising the hay turning system are mounted. The grilles are installed in the tool operating areas as well as in the area where the hand-raked produce is deposited. Plant components that fall through the expanded metal are assessed as shatter losses. Even if this model-based arrangement for the turning processes does not represent an accurate reflection of reality, it has nevertheless proved possible, by means of comparative tests, to determine the influence of tool speed on resulting shatter losses. Similar to the study carried out by Ahmels [6], Manns dispensed with stubbles. It is therefore difficult to state how far this test set-up constitutes an accurate reflection of reality.

### Straightforward, Practical Measurements with Artificial Stubbles

With the aim of achieving a better illustration of reality, a new approach [15] was tested in collaboration with the University of Kassel. After mowing, eight 50 x 25 cm (0.125 sq.m.) wooden boards with 8 cm long artificial bristles made from nylon were laid out on a seeded foraging area (**figure 3**). The standing crop of grassland was characterised by a high proportion of *Trifolium pratense* and *Trifolium repens* (50 % and 7 % share of the standing crop respectively). Shatter losses that ensued during the harvesting process collected between the bristles and were evaluated once the harvest had been completed. One part of the harvested cropland was tilled in the traditional manner using a rotary tedder and turner type Krone KW6.62/4 (two times) together with a Krone Schwadro 38 model swather. The procedure used for the second part of the area involved the use of a type Dion 6096 windrow inverter (windrowing three times). Parallel to the tests with the artificial stubbles, the losses were also determined using the leaf vacuum method. Both methods showed that opting for a traditional approach entailed higher losses than with the windrow inverter (**table 1**). No significant differences were identified between the measuring methods



Fig. 3

Artificial stubbles are still being tested

Table 1

The difference between the harvested yield is shown more exactly by artificial stubbles [15]

Verfahren Procedures	Erträge dt TM/ha Yield dt DM/ha	Verluste [dt TM/ha] Losses [dt DM/ha]	
		Laubsauger Leaf vacuum	Künstliche Stoppeln Artificial stubbles
Schwadwender Windrow inverter	18,4	1,7	1,0
Konventionell Conventional	16,8	2,0	2,9
Differenz Difference	1,6	0,3	1,9

(windrow inverter  $P = 0.116$ , conventional  $P = 0.067$ ). This shows that both methods are suitable for use in calculating the shatter losses.

Higher losses lead to differences in the crop yield. Assuming that the surface on which the trials were conducted was populated with homogeneous growth, the differences in crop yield based on the various harvesting methods will be reflected in a different level of loss. The difference in crop yield between the area that had been conventionally worked and the one tilled using the windrow inverter was 1.6 dt DM/ha. The leaf vacuum method identified loss differentials of 0.3 dt DM/ha between the two harvesting methods. The use of the broom method enables a better interpretation of the actual differences in crop yield (1.9 dt DM/ha). One explanation could be the fact that the result of the test for the leaf vacuum method was ultimately less successful because rain and a thick layer of thatch made vacuuming-off more difficult.

### Conclusions

It has emerged that the results of the studies into shatter losses are affected by a number of constraints. Under open ground conditions, measurements are only possible where there is a sufficient quantity of growth and if the weather is suitable. As far as the extensively used vacuum methods are concerned, the outcome (as reported by Ahmels [6]) may be influenced by organic foreign material. In the same way a dense coverage of grass or crumbled plant residue sticking to the ground due to rain may have a bearing on this method of measurement.

An initial test has indicated that the new approach utilising artificial stubbles is a practical option as well as being easy to handle. Further trials will show whether the method is capable of superseding the leaf vacuum method for practical tests.

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