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Creation of Calculation Models for Estimation of Labour Requirement for Barn Dried Hay Production and Its Feeding on Dairy Farms

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The feeding of dairy cows with hay and production of so-called “hay milk” becomes an interesting production alternative for dairy farmers in some European countries. To minimise weather risk during hay production and to produce hay of high quality, the interest of farmers in barn hay drying techniques is growing. However, there is limited information available regarding labour requirement for barn dried hay production and its feeding by current used techniques.
The aim of this study is to create calculation models (MS-Excel based) for the estimation of labour requirement for loose barn dried hay production (from harvesting until storing) and its feeding to dairy cows. Different variants with loader wagon (in use for harvesting and feeding) and hay crane (in use for filling up, shifting and emptying of drying boxes and also for feeding) are studied.
To determine the standard times for individual work elements of interest, the selected tasks are timed on the level of individual work elements by the digital device Multidata (Drigus). Moreover, influence variables and procurement quantities (volumes, distances etc.) necessary for determination of standard times are recorded at each timing.
The recorded data are regularly statistically evaluated (based on the data evaluations applied in the software Meza (Drigus) and SigmaPlot) to estimate if further measurements are necessary to be performed to obtain reliable standard times. Reliable standard times should have an accuracy of 10 % and 95 % confidence level. The standard times together with influence variables will be included in calculation models to estimate the labour requirement for the selected tasks. The calculation models should enable to calculate the labour requirement for existing farms as well as for “fictitious” farms depending on herd size and desired farm design.
The timing of tasks by hay production will be performed during several cuts in course of this year. The time studies by feeding have started in March this year and will continue over the year. The first measurements were performed by feeding with the hay winch crane with remote control. The works on creation of calculation models for this variant have started as well, and preliminary data for this variant can be presented. For other variants and for tasks during dried hay production, the creation of calculation models will start after first measurements (for other variants by feeding between March and May and by hay production between May and June).
The obtained information should enable the farmer to consider labour requirement for investigated systems regarding and thus support him by the determination those best suited to his condition.

1. Introduction

In Germany and also in several other European countries (Lehnert, 2012), the production of so-called “hay milk” becomes an interesting production alternative for dairy farmers (Huber et al., 2015). However, the weather conditions do not always allow a high-quality hay production. Therefore, the interest of farmers in barn hay drying techniques increases.
In comparison to field-cured hay production, the barn hay drying systems enable to harvest the partially field-cured hay already at 60 % dry matter content (Wirleitner et al., 2014), and thereby to reduce the time of the

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field drying period and also the number of working steps on the field. Moreover, due to lower material disintegration, the field losses of leaves can be reduced (Resch et al., 2009) and hay quality can be increased (Fasching et al., 2015).
The investigations were done also regarding nutritional (Carter, 1960; Resch et al., 2014) and microbiological quality of barn-dried hay (Jakschitz-Wild and Thurner, 2015; Resch et al., 2014). The barn-drying can lead to higher nutrient concentration, forage intake in animals, and milk yield (Resch et al., 2009; Fasching et al., 2015).
However, additional working steps and energy (for forced ventilation, supplemental heat, and dehumidifier) are needed during the barn drying period. Comparisons of energy consumption and costs for different hay drying methods were examined in the study of Pöllinger (2014).
Barn dried hay production changes harvesting in large parts. It requires more batches per cut due to drying capacities, a special harvesting chain with a special time schedule, and further working operations during barn drying. But only less information is available regarding labour time required for barn dried hay production and its feeding. Due to many influence factors, values of labour requirement or input for production of grass silage, field and barn dried hay vary widely in different studies (Eichhorn, 1999; Schick and Stark, 2002; Ammann, 2007; Diverse authors, 2011). Nevertheless, in all studies, the values for production of grass silage in bunker silos was lower than for field dried hay; and further, time required for field dried hay was lower than for barn dried hay. The potential for lower labour requirement will be seen by labour requirement for barn dried hay feeding in comparison to silage feeding (Neuhofer, 2010; Eilers et al., 2013).
Therefore, there is need for information on labour requirement of recently used techniques by harvesting, storing, and feeding of barn dried hay. Such information would enable the farmer to consider the advantages of various systems and thus determine those best suited to his condition. The hay drying in barn can be performed in loose or baled form. The loose drying is performed in so-called drying boxes. These boxes are mostly filled up with a hay crane which can be frequently used also for feeding. The production of loose barn dried hay is the system of interest to be studied in this investigation.
The aim of the study is to evaluate the labour input for loose barn dried hay production (from mowing until the dry hay is stored) as well for its feeding by application of forage wagon (for hay harvesting and processing as well as feeding) and hay crane (for filling up and emptying of drying boxes and also for feeding) on Bavarian dairy cow farms. The obtained data will be used to create calculation models for the estimation of labour requirement for the techniques of interest as well as their objective comparison.

2. Material and Methods

Time studies will be performed on Bavarian dairy farms. Ten farms are already participating in the study. The herd size of these farms varies between 15 and 100 cows. On four farms, besides hay also grass silage is fed.

2.1 Timing of selected tasks

To determine the standard times for work elements of interest, the time recording is performed on the level of single work elements. Consequently, all tasks/subtasks performed by application of chosen techniques are divided to individual work elements with definition and describing of beginning and end points. By barn dried hay production, the following steps are of interest: mowing, tedding, windrowing, raking, loading, transport, unloading, storage, and all operation performed during the drying process (e.g. turn on/off applied technics, inspections, restoring). By feeding, they are: feeding the hay (i.e. loading, transport the hay to the stable, and discharge of hay on feed table), pushing the hay to cows, and removal of hay remains.
The time recording is performed only by work elements for which the standard times are missing in our standard time data (i.e. collection of standard time values for individual work elements). The tasks are timed using direct observation using a timekeeping device MULTIDATA (Drigus). During each time recording, influence variables on each element (volumes, distances, amounts etc.) are recorded (e.g. by reloading of hay into drying boxes: weight and humidity of hay, capacity of hay crane and drying boxes, and distances between place of unloading and drying boxes, by feeding: weight of hay discharged on feed table, capacity of hay crane or loader wagon, distances between storage place and feed table, and length of feed table). Additionally, the data about operators, the operations, layouts, and technical parameters of machines are collected during each time recording.
The recorded data are regularly statistically evaluated (based on the data evaluations applied in the software Meza (Drigus (Drigus, 2010)) and SigmaPlot) to estimate if obtained data are reliable or further measurements are necessary to be performed to obtain reliable standard times for individual work elements. Examination of the required number of observation (n') is performed under the terms of an accuracy of 10 % (for our processes sufficient according to REFA (1972)) and 95 % confidence level. Obtained standard times (reliable mean values or regression functions) will be included in models as well as in our standard time data.

The time recordings by feeding with hay winch crane with remote control (Figure 1) have started recently.

2.2 Creation of calculation models

Computer based calculation models (MS Excel format) will be developed to estimate the labour requirement associated with dried hay production, harvesting, and feeding for technique of interest. The standard times obtained during time studies together with influence variables will be ongoing included in the created calculation models.
The calculation models consist of three parts (Figure 2): 1) fields for entry or calculation of influence variables (when no entry will be carried out, the calculations can access constants or default values by some variables), 2) standard time data (standard times for individual work elements performed by tasks of interest), 3) the calculations (i.e. the equations with logical links between influence variables and standard times) for estimation of time required for individual work elements. The time required for the task of interest is the sum of the times for all work elements done to perform this task.

Figure 1: Hay winch crane with remote control in park position over the drying boxes

2.3 Working dairies

Besides timing of selected work elements by direct observation, the recording of labour input for barn dried hay production and its feeding will be performed also using working dairies. During representative periods, all farm operators included in these processes have to record the time needed to perform the tasks of interest.
For the production and harvesting of barn dried hay, the labour input will be recorded during several cuts within one year. Additionally, automatic data recording is planned to be performed by GPS data loggers during field work on several farms during some cuts.
Due to the fact that the cows are grazing or fed with green fodder in the barn during summer on some farms, the recording of labour input for feeding and other tasks connected with feeding will be performed daily during two periods of 14 days; i.e. two weeks in summer and two weeks in winter. To obtain the data also for irregular work operations related to feeding, a query will be performed additionally.

3. Results and discussion

3.1 Barn dried hay production

The timing of work elements during the barn dried hay production will start at the first cut in this year. Most work elements of interest are elements connected with reloading of hay from a forage wagon to drying boxes and the drying process.

The first results can be presented at the end of May.
However as expected, the preliminary results of the labour input recording by work diaries on 3 farms during the last cut in 2016 showed that notably higher labour input can be expected by dry hay production in comparison to silage production. To reach at least 60 % of dry matter, the number of steps on the field for tedding and raking was at least once or twice higher. Higher seems to be also the time consumption for the storage and drying process in drying boxes.

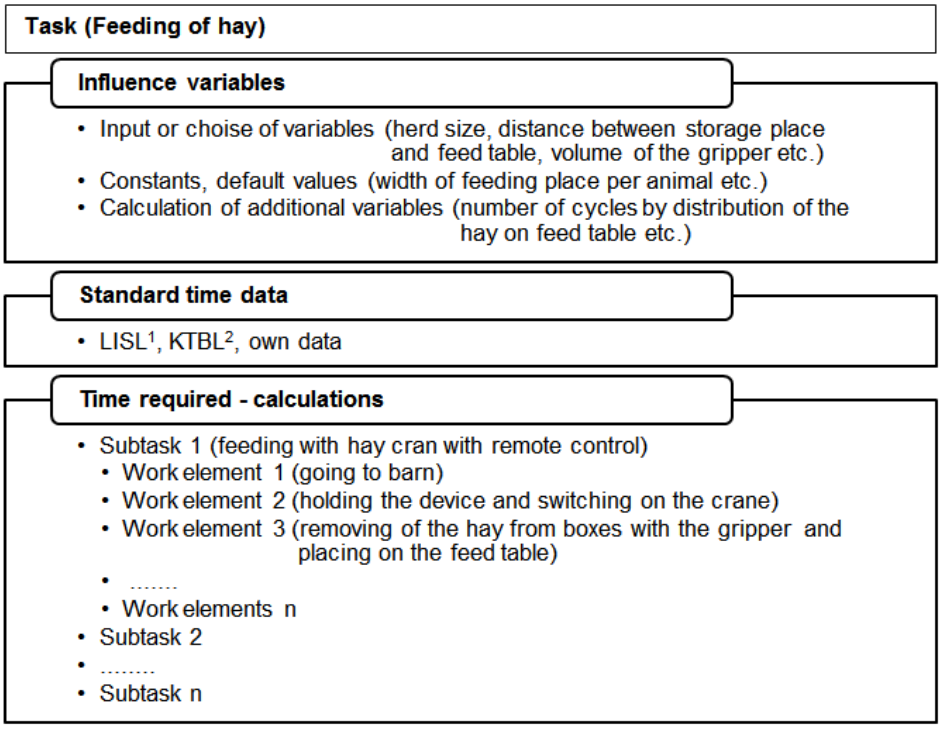

Figure 2: Structure of calculation models ([1] Landwirtschaftliches Informationssystem Landtechnik, [2] Kuratorium für Technik und Bauwesen in der Landwirtschaft)

3.2 Barn dried hay feeding

At meantime, the first timings were performed by application of overhead winch crane with remote control. Additionally, also the works on creation of calculation models for estimation of labour requirement by feeding of barn dried hay have started. Numerous variables can be considered in calculation models, e.g. herd size, length of feed table, feeding frequency, maximal volume of gripper for removal of hay from boxes, hay ration, distance between storage place and barn etc.
The composition of the hay ration belongs to one of the most important influence variables. In the calculation models, the real hay ration can be entered or the ration can be calculated according to milk yield (thereby different feeding groups can be considered), average animal weight as well as the stage of gravidity in dry cows. Energy requirement is calculated according to net energy of lactation, energy for body maintenance, and additionally energy need for gravidity by dry cows (Meyer, 2005; Gruber et al., 2008). Thereby, the metabolic energy of hay and concentrate as well as the displacement effect of concentrate on hay intake can be considered. Example calculations of hay rations for dairy cows according to milk production and metabolic energy of hay and concentrate at 700 kg live weight are shown in Table 1. The calculated values are inclusive of 5 % of allowance by hay (to ensure ad libitum feeding and to take into account the losses). The value of allowance as well as most of other influence variables can be modified.
The calculated ration values are also used to calculate needed storage capacity and thereby size of storage place when these parameters are not entered.
To enable example estimation of labour requirement for feeding by the crane with remote control, the preliminary standard times were estimated. They are not yet reliable and additional measurements have to be performed. Table 2 shows estimated time required per cow and year for hay feeding (i.e. for removal of hay from boxes and its distribution to cows on feed table) once daily by hay winch crane with remote control

according to herd size and maximal volume of gripper. Additional settings for calculations of labour requirement and hay ration were: year-round stable feeding of hay ration, one-sided feed table, metabolic energy of hay and concentrate 6.5 and 7.5 MJ/kg dry matter, resp., milk production 30 kg per day and cow, live weight of cows and maximal hay dry matter intake were set up as in Table 1.
The time required for feeding per cow and year ranged between 2.90 and 3.47 h by the lowest tested maximal volume of gripper and between 1.22 and 1.60 h by the highest tested maximal volume of gripper. Thereby, as expected, the labour requirement decreases with increasing maximal volume of gripper, but not with increasing herd size. Eichhorn (1999) showed that 5 h per cow and winter feeding period were needed by exclusively barn dried hay feeding. In a more recent study, the labour input per cow and winter period for hay feeding ranged between 1.0 and 1.5 h and this inclusive feeding of breeding animals (i.e. 65 cows and 50 breeding animals). The technical details of used crane are not mentioned in the study. But it can be supposed that a more effective telescopic boom crane with cabin was used in that study. The labour requirement by using of this type of crane should be also investigated in our study.
Similarly, the calculation models will be created also for other feeding variants; and that, by application of hay crane for removal of hay from boxes but its distribution in barn by forage wagon.

Table 1: Calculated hay and concentrate amounts per day and animal (kg) in barn dried hay rations for dairy cows according to milk production and metabolic energy of hay and concentrate at 700 kg live weight*

Milk yield (kg/day and animal)	Feed component	Metabolic energy (MJ/kg DM[1]) Hay/Concentrate 6.0/7.0	6.5/7.0	7.0/7,0	6.0/7.5	6.5/7.5	7.0/7.5	6.0/8.0	6.5/8.0	7.0/8.0
15	Hay	17.85	16.48	15.30	17.85	16.48	15.30	17.85	16.48	15.30
	Concentrate	0	0	0	0	0	0	0	0	0
20	Hay	20.36	19.53	18.14	20.37	19.53	18.14	20.37	19.53	18.14
	Concentrate	0.65	0	0	0.60	0	0	0.56	0	0
25	Hay	20.06	21.37	20.97	20.09	21.38	20.97	20.11	21.38	20.97
	Concentrate	3.59	1.07	0	3.34	1.00	0	3.11	0.93	0
30	Hay	19.76	21.07	21.23	19.81	21.10	21.25	19.85	21.12	21.26
	Concentrate	6.54	4.04	2.45	6.07	3.75	2.27	5.66	3.49	2.12
35	Hay	19.46	20.77	20.93	19.53	20.82	20.97	19.58	20.86	21.00
	Concentrate	9.48	7.00	5.44	8.80	6.50	5.04	8.21	6.06	4.70

[1] Dry matter
* Inclusive of 5 % of allowance, maximal hay dry matter intake was set up to 18 kg per animal and day

Table 2: Time required per cow and year (h) for feeding of hay to dairy cows once daily by hay winch crane with remote control according to herd size and maximal volume of gripper

	Maximal volume of gripper (kg)			
Herd size	100	150	200	250
20	2.90	1.78	1.78	1.22
30	3.02	2.18	1.75	1.33
40	3.23	2.17	1.82	1.46
50	3.47	2.22	1.91	1.60
60	3.73	2.59	2.03	1.46

4. Conclusions

While the recording of labour input on farms reflect just the work situation of those farms, timing of individual elements with estimation of standard times for these elements and created calculation models enable objective estimation of time required for evaluated tasks for different farm situations.
The calculation models should enable to estimate the labour requirement for dry hay production as well as for its feeding by application of forage wagon (for hay harvesting and processing as well as feeding) and hay crane (for filling up of drying boxes and also for feeding). Thereby, calculation should be possible for existing farms as well as for “fictitious” farms depending on herd size and desired farm design. This information should support the single farmer by estimation of the labour requirement by application of investigated systems and thus determine those best suited to his condition. Moreover, the obtained data are also important for estimation for hay production costs.

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