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Processing White Asparagus

Optimal Human-Resource Allocation

According to manufacturers, up to 36,000 spears of white asparagus can be sorted per hour with optical grading systems. Horticultural enterprises do not achieve these capacities. Large variations in human productivity and constructional shortcomings when placing the spears into the machine manually are two of the reasons. To efficiently exploit the high capacity of modern sorting machines further research and optimisation of the manual input step are required.

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Keywords

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Literature

[1] *Ziegler, J.*: Bleichspargelanbau. Neustadter Hefte (2002), Heft 101, 4. Auflage

[2] *Jakob, M. und M. Geyer*: Gestaltung von Mensch-Maschine-Systemen im gartenbaulichen Nachernteprozess auf der Basis bewegungsanalytischer Untersuchungen. Zeitschrift für Arbeitswissenschaft (2004), H. 1, S. 53-60

Harvest and processing of white asparagus are very labour-intensive. Processing includes washing, cutting and sorting the spears. All processing units contain a conveyor belt, which is loaded manually and transports the spears throughout the process of washing, cutting and sorting, if done automatically. In smaller enterprises the spears are still sorted by hand, but this job requires a certain experience.

There exist different grading principles. Whereas simple machines just sort by diameter, optical grading systems are based on video technology and image processing. The rapid development of those different automatic sorting units cuts down the relevance of hand-sorting.

The comparison of the theoretical sorting capacities according to the manufacturers information and the effective capacities achieved in selected enterprises reveals a great potential until the maximum exploitation of modern machines is reached.

Motion analysis of manual material input

Within selected enterprises video analysis was carried out, and performance data was collected to detect shortages in the process that need further investigation.

Based on the results, a laboratory work place and homogenous material are used to simulate a simple and highly repetitive process of placing products on a moving conveyor belt. To compare the work process under varying design parameters, a 3-D-motion analysis system collects objective data [2]. A variation of three machine capacities, 7300, 8700 and 10300 spears per hour, are investigated. The distance between the material and the conveyor belt is kept as short as possible. The experimental material consists of wooden sticks with an average length of 42,5 cm and a diameter ranging from 20 to 30 mm.

Active infrared light emissive diodes are attached to both shoulders, elbows and hands of the subjects. The motion data is transformed into space-coordinates to calculate parameters of comparison for the objective evaluation of the work processes. 50 pictures per second are provided.

Performance data of selected enterprises

The collection of performance data on the farms A to H revealed significant differences. Single capacities ranged from 800 to 6 000 spears per hour for the manual material input (see farms A to H in *table 1*). Some of the sorting units offer technical supports for the material input, e.g. an oscillating conveyor. The utilisation of the automatic graders ranged between 58 and 97% of the adjusted capacity. The overall capacities per person showed limited advantages for the automatic graders. The highest machine ca-

Table 1: Performance data taken in various enterprises for different sorting methods and number of workers

Plant	Sorting method	Σ workers	Workers for placing	Capacity p/h	p/h•w	w p/h
A	manual	7	2	5740	820	2870
A	manual	7	2	7980	1140	3990
B	manual	6	1	1600	533	800
C	diameter	17	6	17000	1000	2833
D	optical	9	4	11000	1222	2750
E	optical	9	4	17400	2175	4350
E	optical	9	4	24000	2667	6000
F	optical	11	5	12934	1176	2587
F	optical	11	5	15330	1394	3066
G	optical	13	4	17120	1317	4280
H	optical	7	3	11640	1663	3880

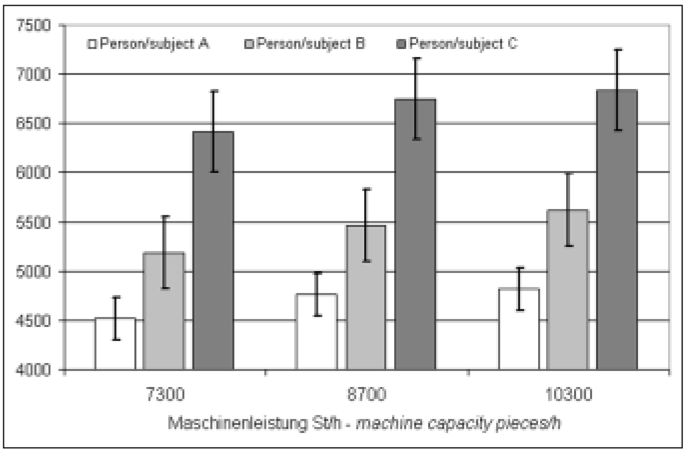

Fig. 1: Hourly capacities of three subjects for placing pieces on a conveyor belt at different machine speeds

pacity was 2667 spears per hour and person. The theoretical performance based on the manufacturer's information are up to 5142 spears per hour and person. This value is considerably higher than the effective data collected in practice.

The basic requirement for a high utilisation ratio is a sufficient material supply. This becomes harder at an increased machine capacity as all workers place their goods on the same conveyor belt. Only the first person in the row finds optimal premises. A second, third or following person fills in the gaps, which can cause interruptions or longer travels for the material. Therefore the single capacities are strongly influenced by the total number of workers in charge of the material input (*table 1*).

Results from the motion analysis

The results from the motion analysis confirmed the existence of strong inter-individual differences concerning the achieved capacities. The speed of the conveyor belt, tantamount to the machine capacity, had a motivating impact on the average personal capacities (*fig. 1*). Apart from the personal capacities there were also noted differences in the amount of motion (*table 2*).

Subject B and C showed higher sums of motion for the upper body in total and for the right hand compared to subject A. For the left hand, the sum of motion was similar for all subjects. An increase of the machine capacity had an impact on the amount of motion of subject A only. The lowest effort per piece was measured for subject A and the highest for B.

Discussion

The farm performance data revealed the unsatisfactory utilisation of automatic graders. Working hours are wasted. Maximum machine capacities range far beyond the effective capacities in practice. The design layout of the manual material input seems to be the bottleneck.

The motion analysis under laboratory conditions confirmed the strong inter-individual differences, although the task was simple and standardised. Subject A showed the lowest effort, but at the same time was the slowest worker. The operation mode also differed between subject B and C. A only used one hand for grabbing a bundle of spears and placed them with the other hand. B and C indeed performed the job two-handed. This explains the higher amount of motion for the right hands of subject B and C. Despite the same mode of operation, subject C achieved respectively higher capacities with less effort. Since all subjects had the same period for training on the job, the different capacities can be explained by varying skills. The observations from the experiments point out the necessity of training, the check of personal aptitude and detailed work instructions, no matter whether the work task is simple or complicated.

Under laboratory conditions the subjects were able to place 4500 to 6800 pieces per hour on the conveyor belt. Compared to the performance data in *table 1*, similar capacities were only achieved in enterprise E. A larger number of workers along the belt reduces the overall capacity and can cause an inhomogeneous distribution of the workload. This limits the advantage to hand-sorting. In comparison to hand-sorting, the time saving is reduced to the process of classification of the spears itself. Nevertheless, the workload for hand-sorting is still higher, the achieved sorting quality less stable and a short-term modification of the sorting criteria is critical.

Frequent crew changes might also reduce the output. The investigation of the most effective mode of operation, followed by a detailed instruction of the workers, guaranties success.

The rapid development of computer technologies constantly increases the theoretical capacities of optical graders. A satisfactory utilisation seems to become irrational if the plant changed is not changed with it.

Table 2: Amount of motion (average of ten trials) at different machine capacities based on 91 sticks per trial

Subject	Sum of motion in total (m)			Sum of motion hands (m) left			right			Sum of motion per stick (m)		
	7300	8700	10300	7300	8700	10300	7300	8700	10300	7300	8700	10300
A	64,22	63,48	65,94	19,59	19,86	20,53	15,26	16,02	16,94	0,71	0,70	0,72
B	96,62	92,73	87,92	21,48	20,95	19,78	23,97	23,07	21,65	1,06	1,02	0,97
C	80,37	81,83	82,22	18,57	18,26	18,02	20,33	20,82	20,55	0,88	0,90	0,90