Soil Spread in Potato Storage Boxes Filled on the Potato Harvester

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ABSTRACT

For uniform quality, potatoes must be sufficiently ventilated during their storage in boxes. Soil and other foreign material that enters the box together with the harvest can impede ventilation. The proportion and distribution of foreign material in the potato boxes are therefore of interest, as both parameters have a crucial influence on the ventilation of the potatoes. In connection with the testing of a potato harvester that fills the potatoes in storage boxes on the machine, the aim was to clarify what proportion and what distribution the foreign material assumes in the box. For reference purposes boxes located on a transport vehicle were filled from the potato harvester hopper too.

The content of foreign material and its distribution in the storage boxes were determined using a tipping method and a sampling cylinder method. The examinations were concentrated on foreign material with a diameter of less than 2 cm. In addition, the extent to which the storage boxes were filled was determined by weighing.

It turned out that filling the boxes on the harvester leads to uniform distribution of foreign material by contrast with filling boxes located on the transport vehicle. Thanks to gentle filling on the harvester, the clods did not disintegrate into loose soil so that there was only a small proportion of foreign material with a diameter of less than 2 cm.

Keywords: Potatoes, harvest, storage boxes, foreign material distribution

1. INTRODUCTION

The quality of table potatoes depends on how gently the potatoes are harvested and stored and what conditions prevail during the storage period.

As already reported in a previous paper (Maly et al. 2005), it is beneficial for the potato quality if the potatoes are filled in storage boxes already on the harvester. This process is described below as direct box filling. The tubers are conveyed to the store in the boxes and taken into storage without any further tuber handling processes.

As a consequence of the gentle filling of the storage boxes on the harvester and storage intake without mechanical stress, it was possible to achieve a distinct reduction in black spots (Maly et al. 2005). In the case of one delicate variety the incidence of black spots was halved by comparison with bulk storage.

When the boxes are filled on the harvester, the box and feed belt are displaced in relation to each other several times (Figure 1) so that the box is filled evenly in layers (Maly 2005). As a consequence of this filling method it could be expected that the foreign material would not accumulate in the middle of the box, but instead that tubers and foreign material would be spread uniformly throughout the box. The uniform distribution of foreign material is particularly important in the case of ventilation by free convection. In this type of ventilation the natural lift of the air as a consequence of temperature differences is used. Free convection ventilation is very favourable in energy terms because it does not require any fans. However, there is a risk that tuber batches with a high content of foreign material might not be ventilated enough, if at all.

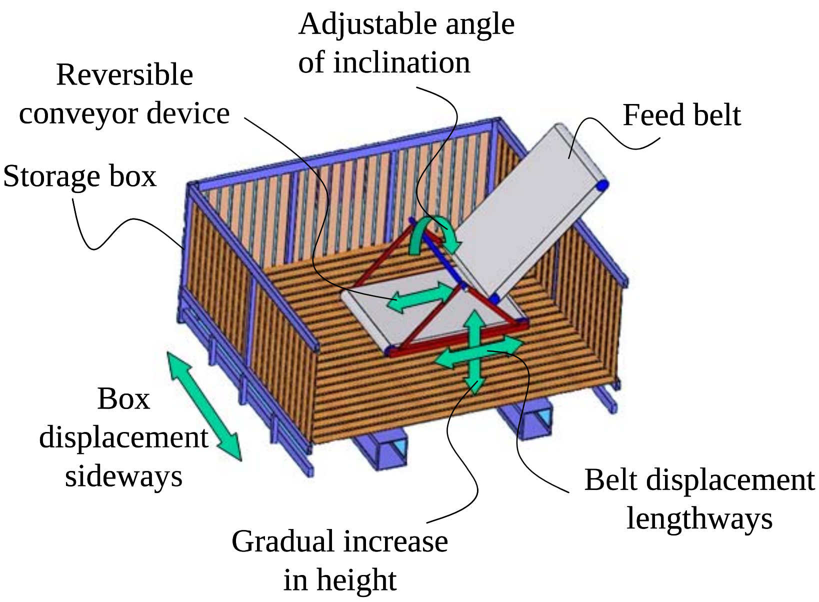


Figure 1: Box filled in layers by displacing the box and filling belt in relation to each other and increasing the height of the filling belt in steps

Within the scope of four-year investigations the aim was to clarify how filling the boxes on the harvester affects the distribution of the foreign material in the box. A further, subsequent paper will show what influence the distribution of the foreign material has on the air flow through the box content (Hoffmann et al. 2007).

2. KNOWLEDGE STATUS

Several variants exist for potato storage:

- *Bulk storage*: The tubers are taken into storage after being delivered loosely in bulk piles at the store. Devices for separating the foreign material are used in the machine chain for storage intake. Consequently the potatoes in storage are largely free of loose soil.
- *Box filling on farm*: Potatoes are harvested loose in bulk and transported to the store. Directly before storage intake the tubers are filled in boxes. As with bulk storage, devices for separating the foreign material are used.
- *Indirect box filling*: Transport vehicles with storage boxes take over the tubers from the harvester hopper on the field. The foreign material is filled in the boxes with the tubers. The boxes are taken into storage without separating out the foreign material (Maly et al. 2005, Horlacher 2004).

- *Direct box filling*: The boxes are filled with tubers and any foreign material on the harvester (Maly et al. 2005). The boxes are handed over to transport vehicles and taken into storage without foreign material being separated out at all.

The terms *Bulk storage*, *Box filling on farm*, *Indirect box filling* and *Direct box filling* are always understood to mean the entire process chain with harvesting, transport, storage intake, storage and storage outtake.

In the case of bulk storage and box filling on farm, the foreign material is largely removed by separation. For this the tubers are subjected to frequent mechanical stress, however. The tubers are taken into storage much more gently in the variants indirect and direct box filling.

The foreign material consists of stones, clods, weeds and soil. The proportion by weight of soil in the potatoes harvested ranges from 5 % to 30 % (Scheer 1999). Kolchin (2004) quotes foreign material shares of up to 45 %. The storage of tuber batches rich in foreign material is always connected with extra costs and quality losses:

- As a result of the proportion of foreign material it is not possible to make complete use of the volume of storage space available.
- Foreign material shares with a diameter < 2 cm jeopardise ventilation of the potatoes during storage (Matthies 1956)
- Above all, when potatoes are harvested under wet conditions clods and loose soil bind free water which can only be removed from the stored material with difficulty (Scheer 1999)

Poorly ventilated and moist batches of tubers present favourable conditions for the development of storage diseases (Turkemsteen and Mulder 1996, Langerfeld and Leppack 1992, Beyer 2000). Often the tubers begin to germinate before expiry of natural dormancy (De Weerd 1995, Allen et al. 1978).

In the case of direct or indirect box filling on the field it is hardly possible to separate the foreign material from the harvested tubers completely. In order to keep the influence of the foreign material on ventilation of the tubers during storage as low as possible despite this, the foreign material should not be concentrated in one part of the box, but instead must be distributed as evenly as possible through the entire volume of the box (Boumann 1998).

Examinations of the distribution of foreign material in boxes are known only from Horlacher (2004). Horlacher emptied by hand boxes that had previously been filled from the hopper of the harvester. The proportion of foreign material remaining after the tubers were removed was measured. It became apparent that there was 30 % more foreign material in the middle of the box than at the edges of the box. The reason for this was considered to be that tubers and foreign material became de-mixed during filling of the hopper and transfer of the tubers from the hopper to the box. As a result of the method applied, Horlacher was only able to determine the distribution of foreign material related to the base area of the box. The high time input required meant that only a small number of boxes could be examined.

3. MATERIAL AND METHODS

Our own investigations aimed to determine the distribution of foreign material inside the box for both direct and indirect box filling. The examinations were conducted in connection with practical trials of a Grimm SE 150-60 harvester with a box-filling facility (Maly et al. 2005). The harvester trials and examinations of foreign material distribution were conducted at Friweika Weidensdorf e.G. (Germany, Saxony). The company has storage capacity for approx. 30,000 t potatoes, including 15,000 t in boxes.

Six potato batches were selected for the examinations (Table 1). In order to achieve comparable measuring conditions for the two box filling processes, the two methods – direct and indirect - were always applied on the same field at the same time. Thanks to good lifting conditions, the content of foreign material in tuber batches 1 to 5 was below 5 %. Foreign material only totalled just under 26 % for tuber batch 6.

Table 1. Lifting conditions and additive shares in the potato batches examined

Tuber batch	Variety	Lifting conditions	Total foreign material [%] *
1	Marena	crumbling soil, no clods	2.67
2	Möwe	soil with clods	4.75
3	Sanira	no clods	3.69
4	Prinzess	with clods	4.12
5	Donella	not clods	3.44
6	Milva	not crumbling soil, many clods	25.75

* Stones, clods, weeds, loose soil

Two methods described as the tipping method and the sampling cylinder method were developed to determine the distribution of foreign material.

With the tipping method, in the years 2003 and 2004 altogether 40 boxes each with 4 t potatoes were tipped empty and the distribution of the foreign material was examined. The tuber batches 1 to 5 were used for the examination (Table 1). Each tuber batch consisted of 8 boxes, in other words 4 boxes from direct filling and 4 boxes from indirect filling.

The boxes (1) were tipped on a tipping line (Figure 2). This consisted of a tipping station (2) and a wide discharge belt (3), 5 m long and 2.7 m wide. After the boxes were tilted at the tipping station, the tubers were tipped from the box onto the slow-moving discharge belt, so that the harvested material spread over the entire length of the conveyor belt. The harvested material fell from this conveyor belt over 4 steel rollers (4) onto a belt running crossways (5).

Thanks to the orderly emptying and distribution of the tubers on the discharge belt (3) it was possible to subdivide the mass of tubers lying on the belt into 12 hypothetical sections (A-L). Each section corresponded to one section in the filled box prior to tipping.

The rollers (4) at the end of the discharge belt were arranged at clear intervals of 2 cm. When the tubers were transported over the rollers, foreign material with a diameter of up to 2 cm fell between the rollers and was caught in three containers (6).

For the evaluation of the soil distribution 4 boxes of each process variant were tipped out. For each box the proportion of foreign material with Ø < 2 cm was determined separately according to the 12 sections (A - L). For the 48 sections of each process variant (4 boxes, 12 sections per box) the mean value, the standard deviation, and the variation coefficient were calculated.

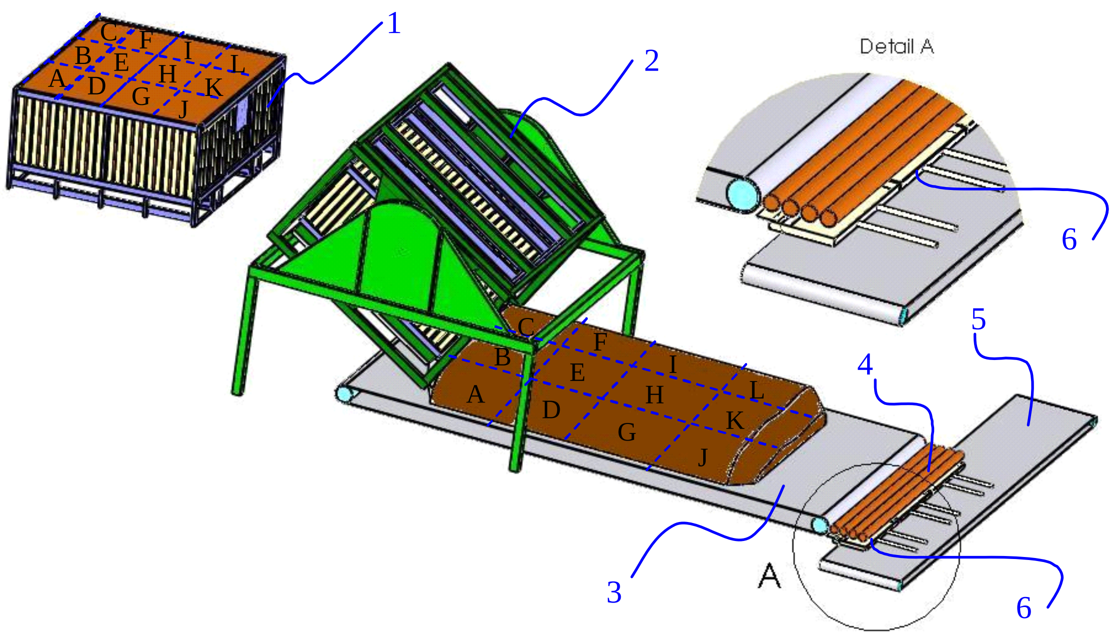


Figure 2. Schematic structure of the experimental arrangement
(1) Storage box with the sections marked, (2) tipping station, (3) discharge belt with the sections marked, (4) steel rollers for removing soil, (5) cross conveyor belt, (6) containers for collecting the separated soil

In the sampling cylinder method three boxes each from direct and indirect box filling from tuber batches 5 and 6 (Table 1) were examined, i.e. altogether 12 boxes. With the sampling cylinder method 13 samples were drawn from each box using a sampling cylinder in accordance with a pattern (Figure 3). The 1200 mm long cylinder with a diameter of 200 mm was pressed through the potato pile from the top to the bottom of the box and then withdrawn (Figure 4).

The side of the cylinder was opened and the contents could be removed, retaining the vertical arrangement of the tubers and foreign material. The contents (approx. 20 kg) removed were divided into three vertical sections, so that each section represented one layer of elevation in the box (Figure 5). The weight proportions of tubers, foreign material Ø < 2 cm and foreign material Ø > 2 cm in each layer in the box were determined.

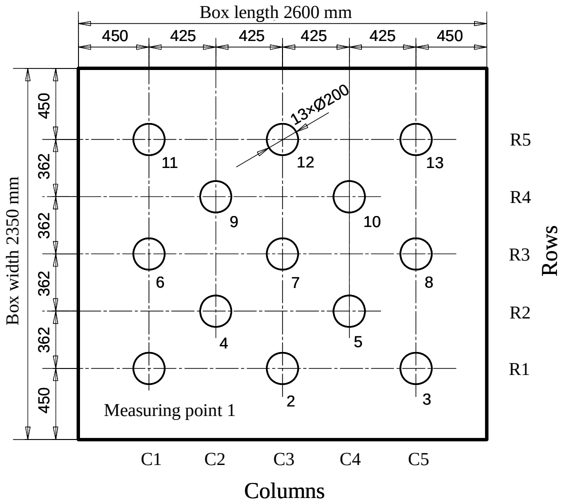


Figure 3. Sampling pattern

Figure 4. Usage of the sampling cylinder

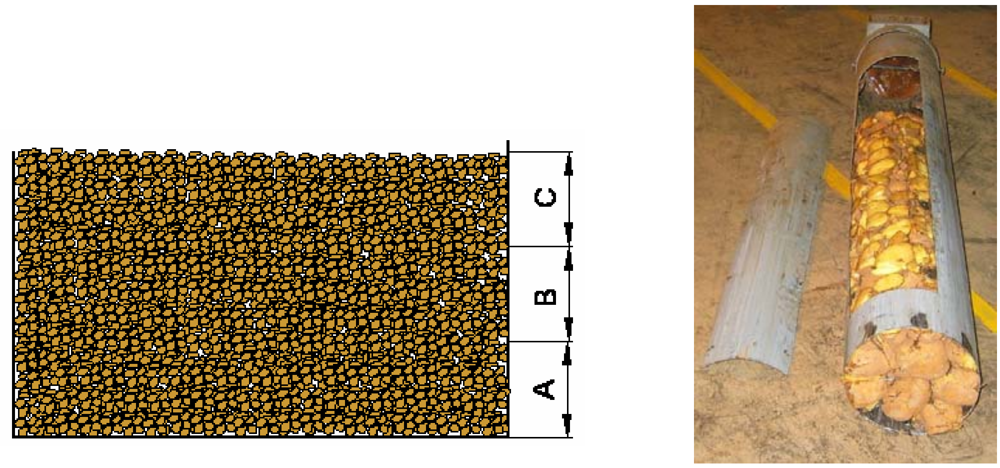


Figure 5. Dividing the box into three vertical layers

The degree to which the boxes are filled is significant if the store capacity is to be utilised in full. In order to determine the degree of filling for direct and indirect box filling, in the years 2002 to 2004 altogether 276 4t-boxes were weighed before being taken into storage in the box store (Table 2).

Table 2. Boxes examined for the degree of filling

Test year	Number of boxes weighed	Variety
2002	177	Solara, Sanira, Likaria
2003	69	Sanira, Marena
2004	30	Prinzess

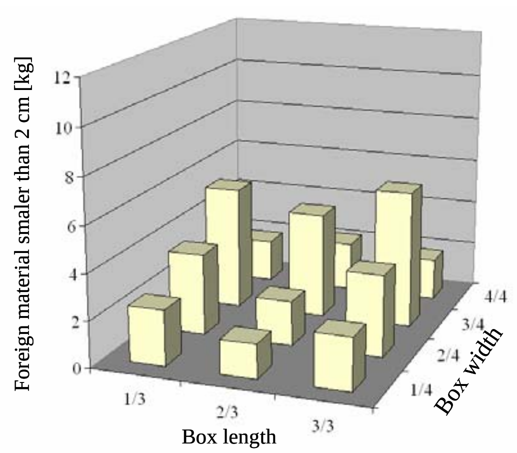
4. RESULTS AND DISCUSSION

The tipping method showed clearly that in direct filling the foreign material was horizontal more uniformly distributed over the box area than in the case of indirect box filling (Figure 6a, b). The more uniform distribution was expressed in a lower variation coefficient of the foreign material distribution (Table 3). Only the third batch of tubers formed an exception. In view of the very low share of foreign material it is to be assumed that this batch showed a random result.

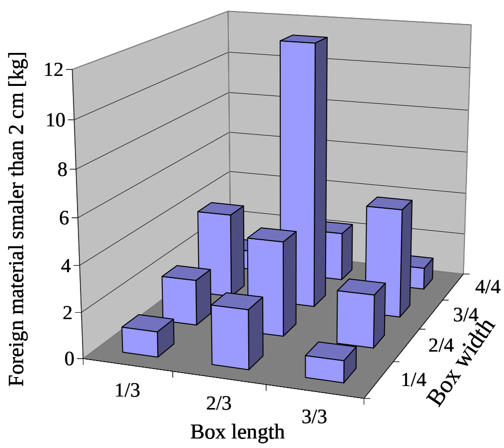
The mean value of the boxes showed a variation coefficient of 46.6 % for direct box filling, which was half that of indirect box filling (93.8 %).

If the content of foreign material in direct filling is set at 100 %, then indirect filling reaches a value of 142.4 % (Table 3). This means that in indirect filling substantially more foreign material with Ø < 2 cm was found, although both filling variants were applied on the same field at the same time with the same type of harvester. The higher mechanical stress on the harvested material during the filling process is thought to be the reason for the higher proportion. When the hopper is filled and the harvested material is transferred from the harvester hopper to the boxes, the tubers with adhering soil and the clods bang and rub against each other. When this happens part of the soil adhering to the tubers becomes detached and some clods disintegrate. Ultimately the content of foreign material with Ø < 2 cm increases.

The high concentration of foreign material in the middle box area and a little off-centre in indirect box filling (Figure 6b) was to be expected on the basis of practical experience and experiments by Horlacher (2004).



a) directly filled boxes



b) indirectly filled boxes

Figure 6. Distribution of the foreign material Ø < 2 cm in the directly filled boxes, mean value of four measurements, variety Prinzess 2004

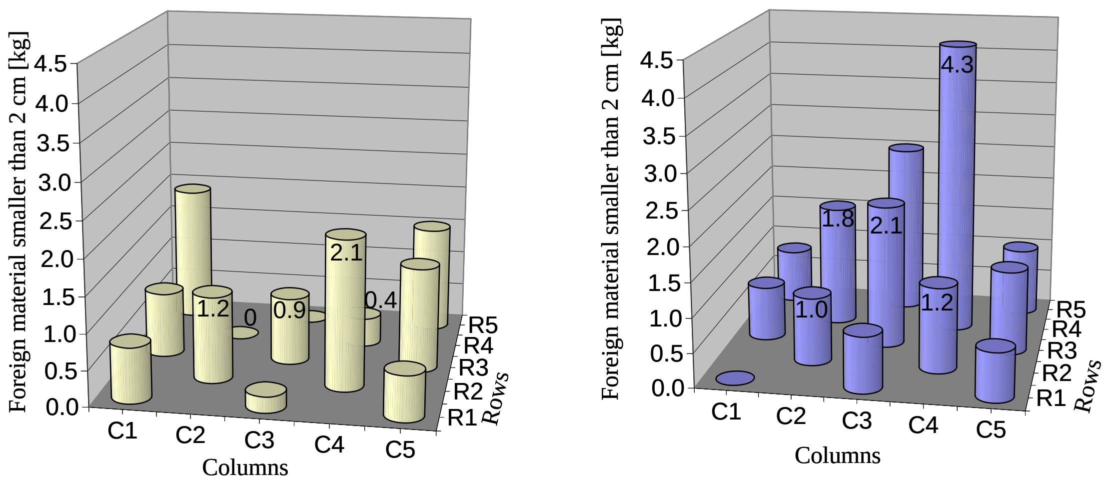
However, our own measurements resulted in a variation coefficient that was 50 % higher than that of Horlacher (2004). This was attributed not only to the different examination methods, but also to the different box sizes. Horlacher (2004) examined 1.5 t boxes, while our measurements were conducted with 4 t-boxes. It is to be expected that with a smaller box volume and base area of the box, the bulk pile and hence de-mixing of the harvested material are reduced.

Table 3. Mean foreign material content Ø < 2 cm in a box section determined by tipping method

		Content of foreign material in a box section					
		direct box filling			indirect box filling		
Tuber batch	Variety	x [kg]	s [kg]	V [%]	x [kg]	s [kg]	V [%]
1	Marena 03	1.06	0.58	54.7	1.97	2.51	127.4
2	Möwe 03	2.52	1.02	40.5	4.25	4.56	107.3
3	Sanira 04	0.48	0.21	43.8	0.44	0.14	32.0
4	Prinzess 04	3.10	1.52	49.0	3.17	3.07	96.8
5	Donella 04	1.34	0.60	45.0	2.27	2.40	105.7
Mean value		1.7		46.6	2.42		93.8
relative [%]		100			142.4		

x… mean value, s…standard deviation, V…variation coefficient V = s / x • 100 %

The sampling cylinder method confirmed the results of the tipping method and provided greater detail.
In Figures 7a and 7b the 5 bars in the middle of the box were labelled with their values. In the case of direct box filling the bars in the middle of the box result to 6.4 kg in the sum. The 5 middle bars for the indirect filling accumulate to 10.4 kg. In the case of direct box filling it became evident that there is particularly little foreign material in the middle of the box. This result is presumably due to the filling process. The filling belt fills from the front part of the box and is then reversed and fills the rear part of the box (Figure 8). Consequently an area with little foreign material results in the middle of the box.



a) direct box filling b) indirect box filling

Figure 7. Distribution of the foreign material Ø < 2 cm in box layer B, variety Milva, measured by sampling cylinder method

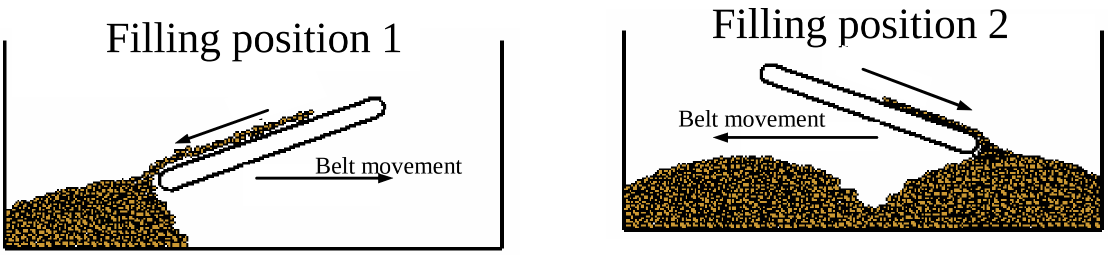


Figure 8. Formation of a low-additive area in the middle of the box in direct box filling attributable to the filling process

The plunger method also supplied results relating to vertical distribution of the foreign material Ø < 2 cm (Figure 9). In direct box filling no significant difference in the content of foreign material could be detected between the middle layer B in the box and the top layer C. In the case of indirect box filling, the middle layer B contained twice as much foreign material as the top and bottom layers C and A in the box.
In both methods only little foreign material was ascertained in the bottom layer A of the potatoes. Presumably small foreign material fell out of the bottom of the box during filling and transporting of the box.

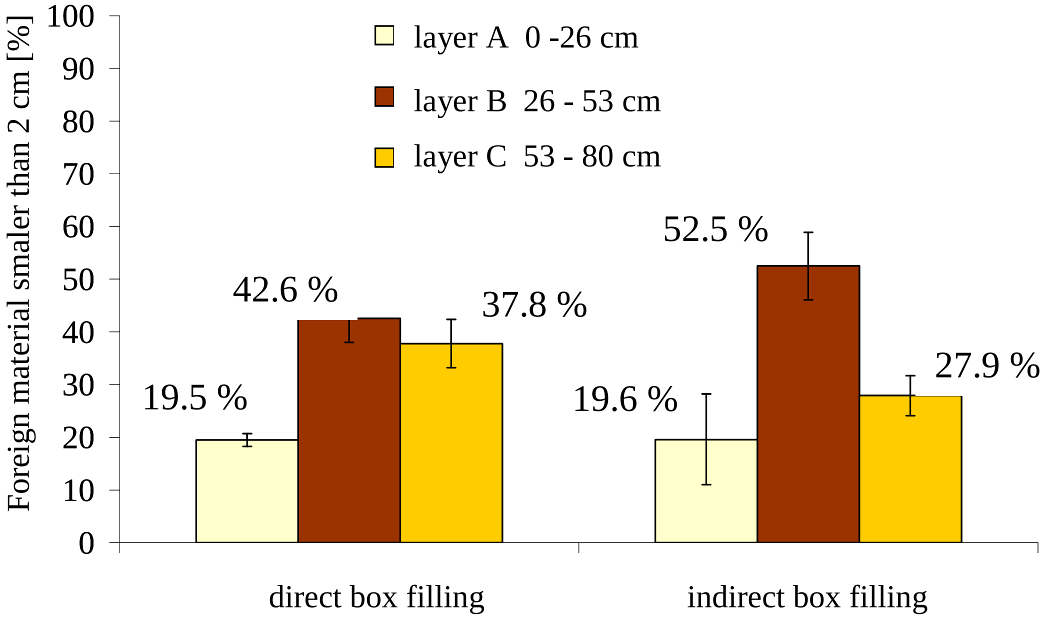


Figure 9. Distribution of foreign material as a function of the pile height
Mean value of three measurements, variety Milva

Direct box filling also showed clear advantages when the degree of filling of the boxes was considered. From 2004 onwards technical improvements in the course of filling made it possible to utilise 100 % of the box volume (Figure 10). The boxes were filled completely right through into the corners and the potato pile projected at most 5 cm beyond the top edge of the case.

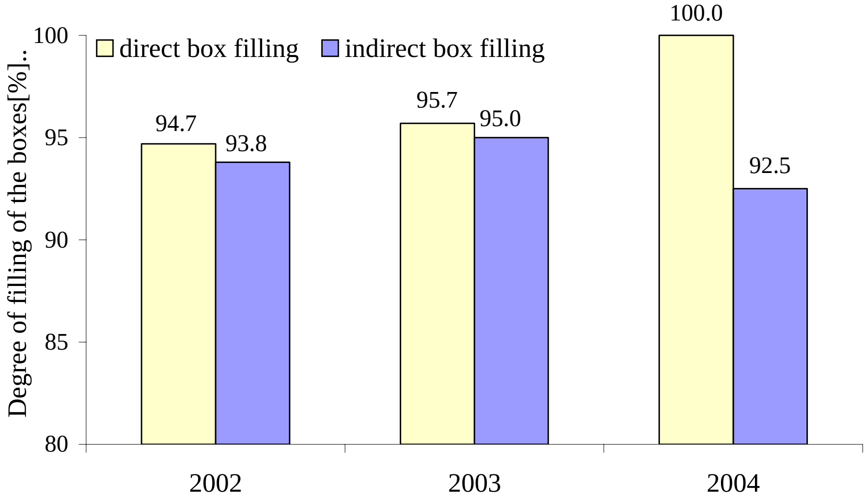


Figure 10. Course of box filling for direct and indirect box filling during the three years of the study

In the case of indirect filling empty box corners and a pronounced pile were ascertained (Figure 11). In some cases the pile was 30 cm higher than the top edge of the box.

Averaged over 30 boxes in the year 2004, the indirectly filled boxes contained 7.5 % fewer tubers than the directly filled boxes. In the case of the firm Friweika considered as an example that can accommodate approx. 3500 4 t-boxes in its box store, the shortfall due to unused storage capacity with indirectly filled boxes amounts to approx. 1050 tonnes of potatoes or 284 boxes a year (Table 4).

Figure 11. Degree of filling for indirect (left) and direct (right) filling of the box

Table 4. Example of utilisation of storage capacity

		Box filling	
		direct	indirect
Number of boxes [1]		3500	3500
Degree of filling of boxes [2]	%	100	92.5
Effective storage capacity	t	14000	12950
Utilisation shortfall	t	0	1050

[1] 4 t potatoes per box
[2] Degree of filling in the year 2004

The storage boxes used in our examinations were relatively large. In order to expand the field of box filling applications on the harvester, the filling facility has been modified. It is now possible to fill two boxes each containing 1.5 t potatoes as well (Figure 12).

Figure 12. Harvesting machine with a device for filling two storage boxes with 1.5 t potatoes each

5. CONCLUSIONS

The tipping and sampling cylinder methods used to determine the distribution of the potatoes and foreign material in the boxes proved successful. The tipping method can be used for rough and fast determination of the foreign material distribution in the box with a large number of test units. However, the sampling cylinder method is suitable for exact determination of the distribution of the foreign material in the box. In this method the content of foreign material across the pile height can also be determined. In view of the high outlay, only a limited number of boxes can be examined. In addition, potatoes are damaged in the sampling cylinder method.

As the uniform distribution of the foreign material is favourable for ventilation, direct box filling is to be preferred to indirect filling.
The fact that gentle depositing of tubers and foreign material in the boxes causes less loose soil than in the case of indirect filling is a further point in favour of direct box filling.

Complete utilisation of the box volume means that a higher degree of filling is achieved by direct filling. Thus the available storage capacity can be used cost-effectively.

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