INVESTIGATION OF MEDICINAL PLANTS DRYING IN BATCH DRYERS – QUALITY AND ENERGY CHARACTERISTICS

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Abstract: *Drying of medicinal plants in Serbia is mostly performed in batch dryers, which offer optimal investment/output rate for most producers. Disadvantages of this dryer type are: higher drying energy and slower through-heating of upper layers, with the resulting increase of microbial count.*

This paper presents results of investigation of peppermint drying characteristics in batch dryer expressed by: essential oil losses, microbial count changes and specific drying energy. Following parameters were measured: fuel consumption, change of material temperature and moisture content in levels 10 cm above grate and 10 cm below surface for three heights of fresh material layer, content of essential oils and microbial count. The drying regime was applied in three different phases.

Results showed that the essential oil losses are acceptable. Microbial count has increased in the upper layer during drying process, while the temperature was less than 45° C for a long period. But during the final drying phase in this layer, the temperature was also over 45° C, and the final microbial count was almost the same for upper and lower levels. The energy input was higher for the 40 cm height of fresh material.

Key words: *Peppermint, Drying, Essential oil losses, Microbial count, Energy*

INTRODUCTION

The safety and quality demands for medicinal and aromatic plants are from year to year higher. Due to risks that occur by natural drying many buyers accept only technically dried products. Compliance with the microbial count limits, based on European Pharmacopoeia (Anonym, 2002) is mandatory in many countries. In developing countries, the use of batch dryers presents a compromise between investments and effects. The control of drying process is very poor in conventional batch driers, resulting in lower quality and higher input of energy. New development of control equipment enables control in batch dryers, which is not only satisfactory but is almost comparable to that in big band driers.

Due to different locations of moisture and bonding forces, the drying process should be performed in phases, with different parameters. Quick evaporation of physically bond moisture typically takes place at the beginning of the drying process. For the removal of moisture located inside of material is, beside the energy for evaporation, the energy for moisture transport to the surface is also needed, (Bruin and Luyben, 1980, Mühlbauer, 1989). This process largely depends on material structure and it differs, e.g. for leaves and stems. Essential oils are active ingredients of many medicinal and aromatic plants, and their thermal sensitivity is a limiting factor for setting up of drying temperature (Mimica-Dukić et al, 2003). Influence of agent temperature on essential oils losses has been reported in many papers. Sometimes authors tend to disregard the difference between material and agent temperature in different phases (Bushbeck et al, 1967, Stakić et al, 1994), which results in low temperature limits being set up. Müller (1992, 2004) has clearly documented that the influence of high temperature on essential oils losses is high in the final phase, especially if material is over dried. Drying temperature has influences on specific drying energy, the higher the temperature the lower the specific drying energy (Müller, 2002). Rise of temperature over 45° C results in considerable reduction of microbial count, due to their dying. Contemporary procedures for reduction of microbial count, treatment with steam or microwaves, are used only in big band driers (Heindl, 2005). In summation, too high temperatures cause losses of essential oils, while too low increase the microbial count. Due to this contradictory requirement the range of auspicious drying agent temperatures is very narrow, especially for final

drying phase, e.g. for moisture content range from 18-20% to the final ones, e.g. 11%. The upper limit, due to essential oil losses is about 50° C, while the lower limit, due to reduction of microbial count, is 45° C. Temperature control can be performed relatively easy in contemporary band dryers (Martinov et al, 2004, Müller, 2004), as opposed to batch driers. The through-heating of whole material layer, upper levels, is very slow, causing increase of microbial count (Graf et al, 2002).

Monitoring of material moisture content during drying process is a serious problem for producers. In the case of a multiphase drying, the moisture content should be measured, while the drying parameters should be changed by reaching defined level of it. NIR and microwave moisture content measuring technique are already used, but, due to high purchasing costs only on big plants, i.e. band driers (Heindl and Heindl, 1998). Simple and inexpensive quick measuring of moisture content can be done using household microwave ovens. The tests of 15 to 30 minutes of drying and calculating of moisture content showed good results, applicable in practice.

The objective of investigation was to test effects of multiphase drying of medicinal plants on essential oil losses, microbial count reduction and energy inputs.

MATERIAL AND METHODS

Material

Cultivar of *Mentha x piperita* L. Danica in first year of vegetation and second harvest, September and October 2005, was used for experiment. Whole plant, i.e. herb, was dried in three heights of fresh material layer: 40, 60, and 80 cm. Material was weighted by mobile balance, acc. $\pm$ 0.2 kg. Material samples for determination of moisture content, essential oil content, and microbial count were taken before drying. In the course of drying, changes of moisture content in the upper and lower levels, 10 cm above the grate and 10 cm below surface were taken for further analysis. At the end of the process, dried material was weighted and samples for determination of essential oil content in both layers were taken. Samples for determination of microbial count were taken as well. Eight tests were made.

Methods

Experimental dryer

Investigation was carried out in special experimental dryer, SD–16 MGA, produced by „Termoplin“ company, Smederevska Palanka, Fig. 1. A 30 kW burner was used, adjusted to operate at its minimum, of about 8 kW. The ventilator was powered by a 0.78 kW electro motor. The agent flow through material layer was adjusted to 0.2 m/s, and measuring was performed with anemometer at overpressure vents opening. The surface of drying grate was 1.6 m^2.

During the course of drying, three working regimes, combination of maximum temperature and working mode –open or circulated– were programmed, Tab. 1.

Table 1. The change of drying regime for three starting heights of dried material

Height of fresh material layer, cm	I phase – open mode, max. temperature 50° C	II phase – regulation, temp. 48° C, changing into open mode at 40% of ag. rel. hum.	III phase – regulation, temp. 46° C, changing into open mode at 30% of ag. rel. hum.
	Duration, h		
40	up to 2	2-8	after 8
60	up to 3	3-9	after 9
80	up to 5	5-13	after 13

Relative humidity of air after passing through material layer was calculated based on temperatures measured by "wet"–9 and "dry" –10 bulbs. The change from open to circulating mode was performed, after reaching the programmed upper value of the relative humidity of the agent, by opening side flaps –4 using a servo-motor –5.

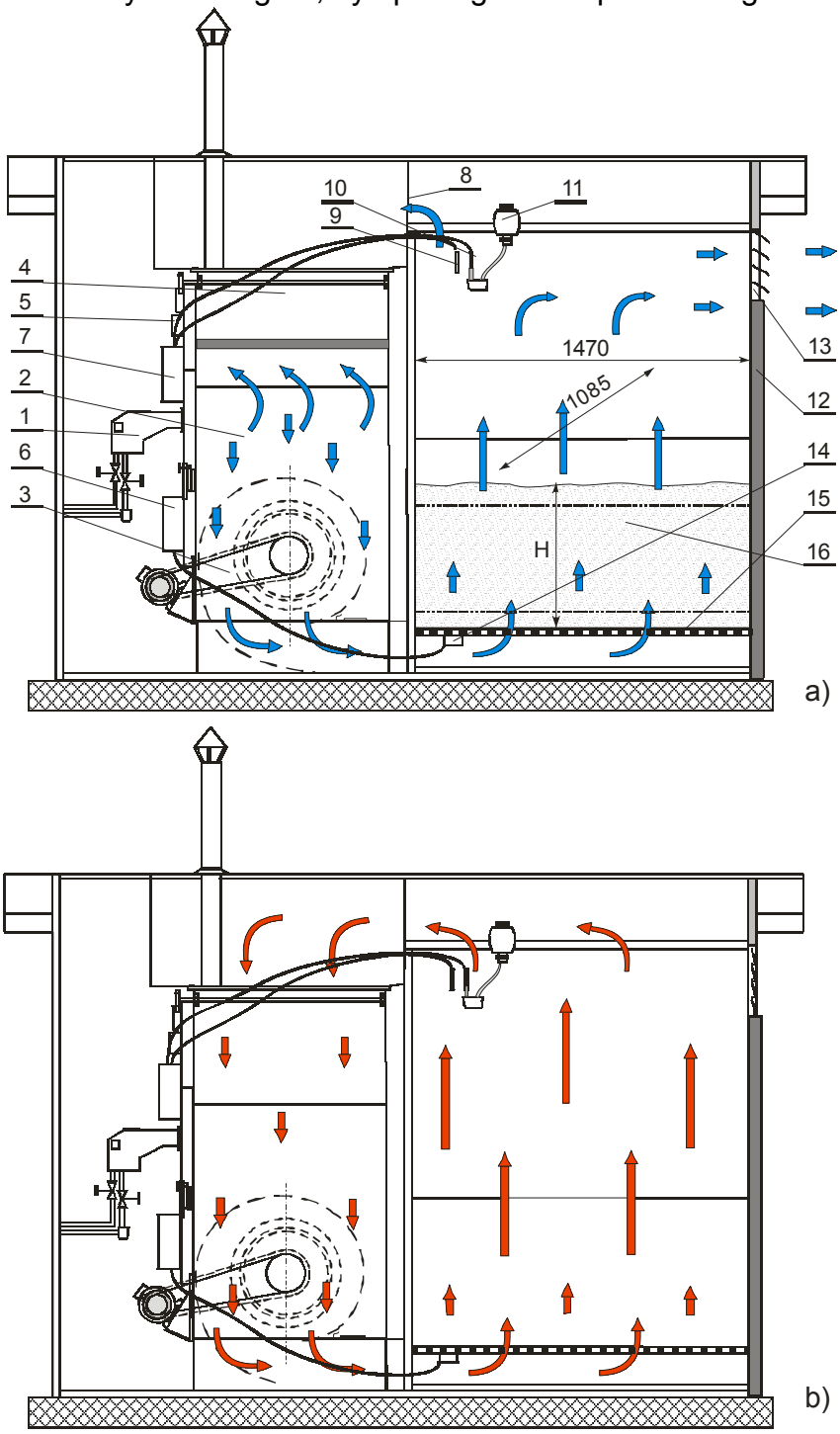


Figure 1. Experimental dryer, a) open mode, b) circulating mode
1– burner, 2– combustion chamber and heat exchanger, 3– ventilator, 4– side flaps, 5– servo-motor, 6– electrical cabinet, 7– control unit, 8– circulation duct, 9– ”dry” bulb, 10– “wet” bulb, 11– water container, 12– door, 13– overpressure vents, 14– thermometer of drying agent, 15– grate, 16– dried material

Fuel consumption was measured by a weighted barrel. Material temperature was measured by Ni–CrNi thermocouples in four points at three levels. The levels were: 10 cm above the grate –*lower*, middle of material layer height –*middle*, and 10 cm below material layer surface –*upper*, in fresh material. The accuracy of temperature measurement was ± 1 K. For temperature recording, data acquisition device Acurex Autodata Nine was used. Specially developed software was used for data processing.

Samples from the upper level, 10 cm below surface, and lower level, 10 cm above the grate, were taken every two hours and used for moisture content determination. Microwave oven was used for quick determination of moisture content. According to the previously provided testing and comparison with the common method, the accuracy was assessed to be ± 2%.

Determination of essential oil

Samples of fresh material were taken for essential oil determination before the beginning of drying – control sample. Sampled material was dried at ambient temperature in ventilated room. At the end of drying, samples of dried material in both upper and lower levels were taken. Essential oil content was determined according to Ph. Jug. V (Anonym, 2000).

Losses of essential oil were calculated in percentages based on the difference in essential oil content between control sample and samples taken from the dried material.

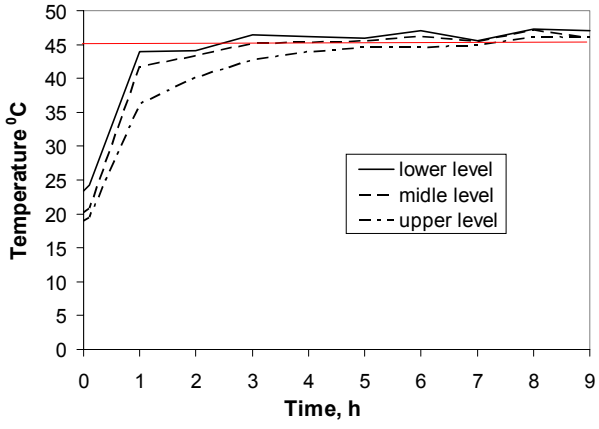
Determination of microbial count

Samples for determination of microbial count were taken from the fresh material before drying and by changing of drying phase, from lower and upper level. The microbial count was determined by methods and in accordance with national regulations.

RESULTS AND DISCUSSION

Temperature course in levels

Examples of measured material temperature courses in three levels are shown in Fig. 2.



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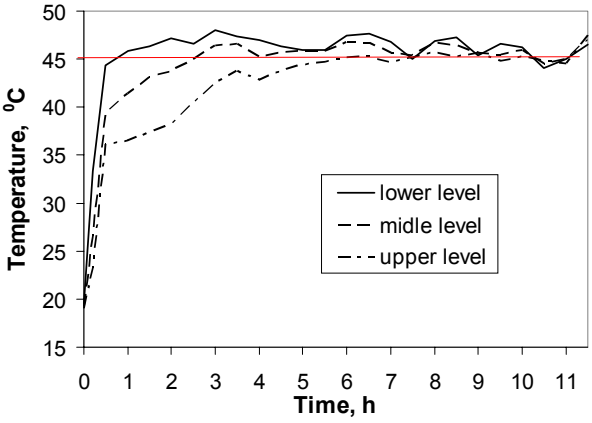

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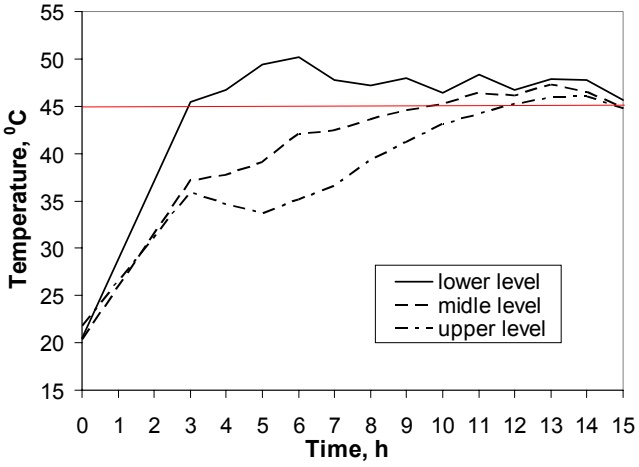


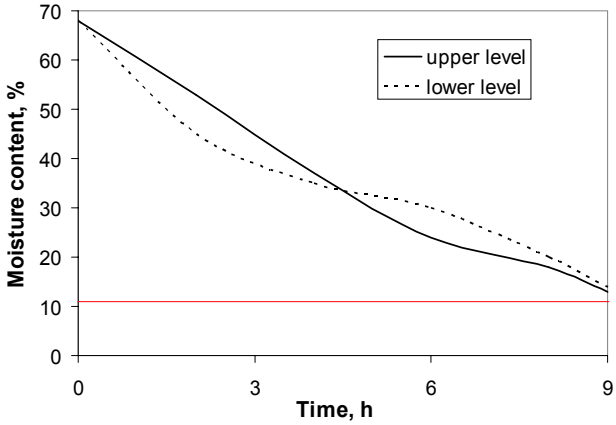
c)

Figure 2. Course of material temperature in levels a) 40 cm, b) 60 cm, c) 80 cm height of fresh material layer

It is evident that material in the upper level reach temperature over 45° C after a significant period of drying. Until this time there exist favorable conditions for increase of microbial count. The higher the material layer height, the longer the time for warming up to 45° C upper level. For example, it takes about 7 hours for 40 cm and 60 cm fresh material layer height, and 12 hours for 80 cm. Reduction of time for reaching target temperature may me possible by turning material layer after reaching certain moisture content of material at the lower level, e.g. 30%.

Course of moisture content

Fig. 3 are presents courses of material moisture content for the same tests as in Fig. 2



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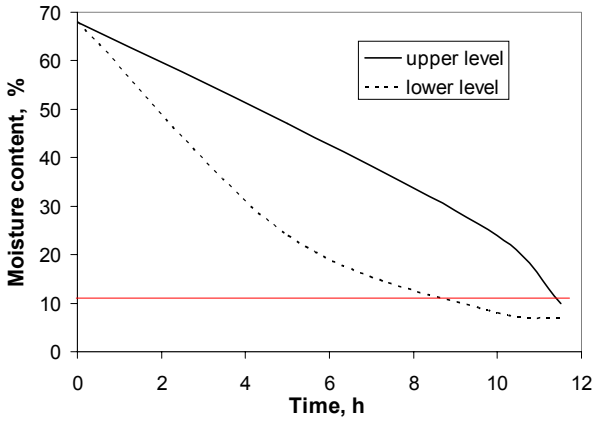

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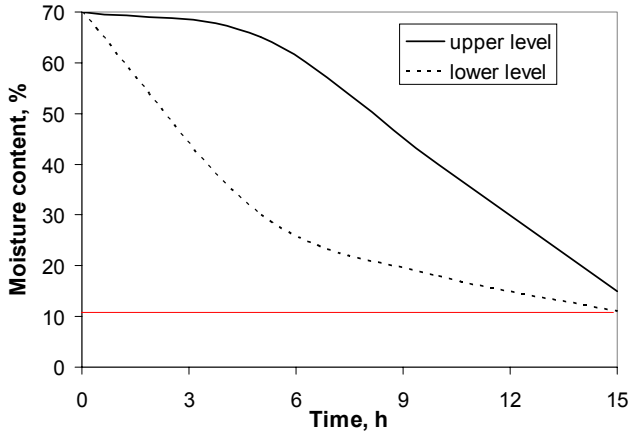


c)

Figure 3. Course of moisture content in lower and upper material levels a) 40 cm, b) 60 cm, c) 80 cm height of fresh material layer

Decrease of moisture content was quicker in lower layer than in the upper level for the 40 cm height of fresh material at the beginning, and later was opposite, Fig. 3a). Average moisture content reduction during drying period was approximately the same for lower and upper level. It can be concluded that for the 40 cm layer there is no significant difference in drying progress throughout material height.

For material layers of 60 and 80 cm, it is obvious that the drying of material in lower level is much quicker than in the upper level, Fig. 3b) and 3c). For 80 cm height of fresh material layer, it can be concluded that the progress of material drying at the lower level starts to decrease at the exact time point when the progress of material drying at the upper level begins to increase - approximately after 5 hours. However, this can not be concluded for the 60 cm layer, with the exception of the last hour of drying.

Here can be also concluded that the drying process for material layers 60 and 80 cm can be improved by turning of material layer after a certain period, for example when the moisture content of material in the lower level reaches moisture content of approximately 25 to 30%.

Losses of essential oil

Measured essential oil losses are presented in Tab. 2.

Expectation that the essential oil losses in lower material levels will be higher than in the upper ones could not be confirmed. In four measurements, losses in the upper level were higher in comparison with the lower one (shaded fields). Larger losses were recorded for testing finished with overdrying of material, where the final moisture content was below 9%.

Essential oil content of material used for testing 80 cm height of fresh material layer was significantly smaller because material was harvested at the end of vegetation.

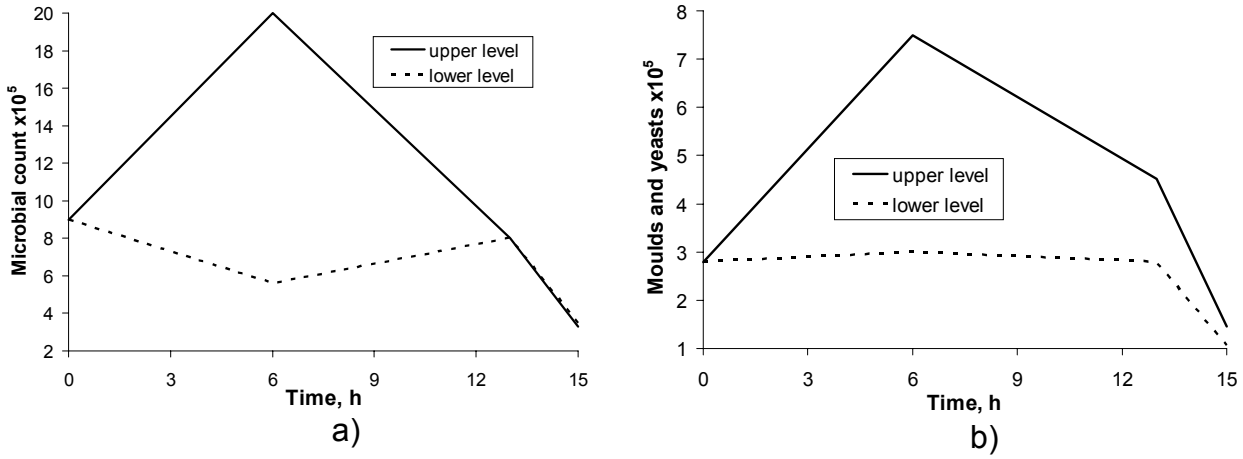
Table 2. Drying losses of essential oils in levels

Height of fresh material layer, cm	Essential oil content in control sample, %	Losses of essential oil, %			
		Level			
		10	30	50	70
40	2.70	15.6	18.8	–	–
40	2.31	4.3	0.4	–	–

60	2.80	31.1	–	17.8	–
60	2.50	9.2	–	11.2	–
60	2.73	16.5	–	8.8	–
60	2.40	3.3	–	7.1	–
80	1.98	2.0	–	–	2.0
80	1.94	7.7	–	–	10.3

Change of microbial count

The change of microbial count in relation with used drying conditions is shown in Fig. 4 a) change of bacteria and b) change of moulds and yeasts.



a) b)

Figure 4. Change of microbial count in upper and lower level for 80 cm height of fresh material layer a) bacteria, b) moulds and yeasts

It is clear that microbial count changed according to the point of sampling. In the material from lower level the bacteria count was reduced during first six hours, slightly increased until about 13 h and than dropped to its final level. The bacterial count in the upper level considerably increased during the first six hours. After the material was heated to this level, the bacteria count was significantly reduced. The similar occurred to moulds and yeasts.

At the end of the drying process equal bacteria count at both levels of material was recorded, followed with a slight difference of mould and yeast counts. Reached microbial count is lower than that of fresh material, and is at the level of 4B category according to European Pharmacopoeia.

Energy

Energy characteristics, calculated from data on fuel consumption, mass of evaporated water, and material mass are given in Tab. 4.

Table 4. Drying energy characteristics

A	Fuel consumption per kg of evaporated water, l/kg e.w.	Specific drying energy, MJ/kg e.w.	Fuel per kg of fresh material, l/kg f.m.	Fuel per kg of dried material, l/kg d.m.
40	0.37	14.0	0.82	0.15
40	0.37	13.9	0.71	0.24
60	0.24	9.1	0.71	0.18
60	0.25	9.7	0.68	0.17
60	0.25	9.7	0.50	0.17
60	0.29	11.0	0.51	0.19
80	0.27	10.1	0.60	0.18

80	0.23	8.6	0.62	0.17

A– height of fresh material layer

Relatively high level of specific energy per kg of evaporated water was recorded. It could be explained with the excessive thermal power of the burner. The average burner efficiency was estimated to ca. 60%. A properly designed and adjusted burner should have efficiency of around 85%.

The highest specific energy was recorded when drying smallest height of fresh material layer. For the 60-80 cm height of fresh material layer, specific drying energy of 6 to 7 MJ per kg evaporated water should be expected, with proper adjustment of hot air generator in practice.

CONCLUSIONS

The results of investigation are in agreement with most of the hypotheses. Drying in phases with defined parameters, results in acceptable losses of essential oil and decrease of microbial count, but the specific drying energy is too high. The drier should be improved by replacing the existing burner with the one of lower thermal power, which should allow better drying temperature control. This measure should yield lower energy input.

The results obtained show that, during first drying phase higher agent temperature can be used, for example 55º. The same holds for the second phase, where the limited temperature should be 50° C. During the final phase, for the reduction of moisture content of material between 20% and 11%, the temperature should range between 46 and 48º C.

The upper material level temperature of 45º C was reached after 7-12 hours, depending on the height of fresh material layer. Microbial count of material decreased after drying in all tests, reaching qualitative group 4B according to European Pharmacopoeia.

In the next season, the plans are to test the effects of prolonging the second phase, up until the material moisture content of 20 to 25% is reached.

The lowest capacity and the highest specific drying energy were recorded for the 40 cm height of fresh material layer. In the future, only batches with fresh material layer height of 60, 80 cm and more, should be tested. Effect of material turning after reducing the moisture content of lower-level material to 25-30% should also be tested.

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