Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 4 (53) No. 1 - 2011

CLIMATIC FACTORS MEASUREMENT IN A WAREHOUSE WITHOUT AUTOMATIC CONTROL SYSTEMS

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Abstract: *This paper presents the variation of climatic factors in a warehouse, for potatoes, without automatic adjustment systems. The measurements were done during the months of December, January and February and they followed temperature and humidity variation inside the warehouse according to the exterior variation of these factors. Also the internal and external temperatures were measured for five representative varieties of potatoes. To make the measurements a portable device for measuring temperature, humidity and air speed and an infrared portable thermometer were used.*

Key words: *measurement of climatic factors, potatoes, warehouse.*

1. Introduction

The significant variation of temperature, light, oxygen, moisture or the lack of water vapors but also the natural enzyme of potatoes tends to deteriorate the products, after a certain period of time. Potatoes, which are perishable products, need certain storage conditions, which will be taken into account when the quality politics is elaborated. It is recommended to avoid: too heavy and voluminous stacks; natural light impact over stored potatoes; high temperatures.

The expiration dates of stored products will be permanently monitored by updating the products inputs and outputs database. Periodically inspections are made for evaluating the potatoes health. If the products had suffered quality deterioration, they must be isolated immediately from the other products.

It must be taken into account that these products have a high water content, which can lead to great losses during their storage. In Table 1 the medium losses from potatoes storage during October-March in different types of warehouses are specified.

Weight medium losses for potatoes storage Table 1

Warehouse type	Weight medium losses, [%]	Weight losses limits, [%]
Ditches in the ground	25.0	8.8…30.3
Huts	17.8	15.0…18.0
Cellars	17.0	12.0…21.3
Modern warehouses	13.8	13.4…14.2

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The functional scheme of a warehouse with mechanical ventilation and without automatic control system for the climatic factors as the one in which the measurements were made is presented in Figure 1. The vertical canals 8 permits directing the atmospheric air flow. The air control system is made through its introduction from the warehouse exterior by the ventilator 1.

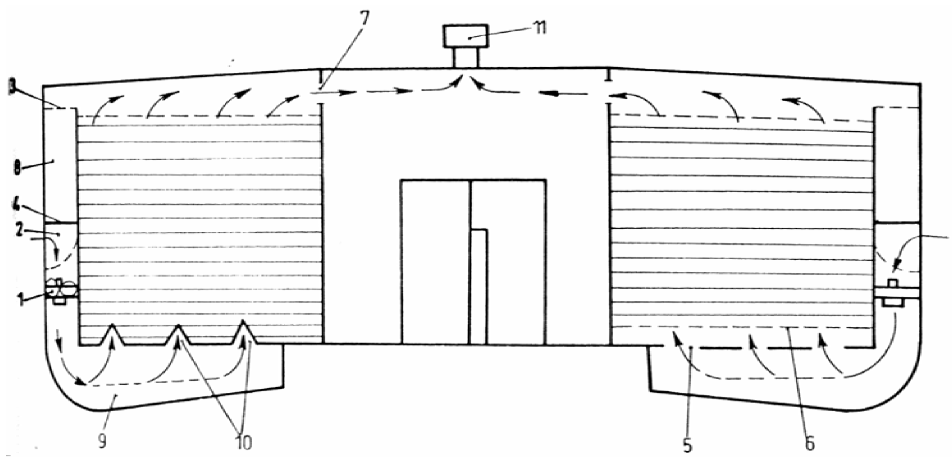

Fig. 1. *Warehouse ventilation installation scheme* [1]

The air enters the warehouse through the opening placed in the leading canals 10 or through the variable dimension canals existing in the perforated floor 6. Because cold air is introduced inside the warehouse a part of the hotter existing air is cooled and another part is evacuated through the warehouse ceiling. The other notations in Figure 1 have the following signification: 2 - routing air flow flap; 3 - excess air evacuation orifice; 4 - air recirculation flap; 5 - ventilation hole; 6 - perforated floor (with variable openings); 7 - ventilation hole to exterior; 8 - air vertical directing canal; 9 - air horizontal directing canal, under the floor; 10 - air flow directing canals; 11 - ventilation hole.

The advantages of warehouses with mechanical ventilation are: in the autumn months the warehouses can be used to pre storing potatoes, which can be subjected to drying by introducing an air flow of 15…18 ºC, which contributes to wound healing and permits storage heights that can reach 4 m therefore, in this manner, the warehouse space is optimally used; during summer the warehouse can be used for drying other agricultural products; uniform temperature and humidity are attained; water condensation is avoided.

The disadvantages of warehouses with mechanical ventilation consist, on the one hand, in the fact that the storing climatic parameters (temperature, humidity, air composition) can’t be controlled and, on the other hand, the air mixture can’t be properly adjusted [1], [6].

For eliminating heat, carbon dioxide and water emitted by the potatoes stored bulk is necessary, through the stored products mass, to permanently circulate a cold air flow. This supposes an air circulation system from the perforated floor to the ceiling, uniformly distributed in the products mass.

Factors which determine potatoes storage necessity are:

• The technical factor which imposes the important deliveries and making some operations which require a certain time and a special technical endowment: conditioning, packaging, labeling, marking, loading, sending, receiving;

• The economic factor synchronizes the agricultural products input with the consumption rhythm, maintains product stocks into an optimal volume for using space and assures the necessary structure for market supplying continuity with necessary products.

The nutritional value of potatoes and their characteristics during the storing period must be maintained, their decrease under certain limits meaning that their introduction into the food chain is impossible [5].

In actual fact, it was proven that in the case of mechanical ventilation, the fruits or the vegetables positioned in the upper part have a higher temperature and humidity. So, for assuring uniform ventilation in the products mass, the height of the stored potatoes inside the warehouse must be as uniform as possible and the potatoe layer situated next to the warehouse walls (where the air flowing is realized more easily) should be approximately 0.50 m higher than the rest of the stored potatoes [2], [3].

2. Material and Method

The measurements were made in 14.12.2010, 20.01.2011 and 23.02.2011 in the mechanically ventilated warehouses of the National Institute of Research and Development for Potato and Sugar Belt Braşov. To eliminate possible measurement errors, each parameter was measured 10 times. In case of any peaks apparition, these were eliminated and afterwards the average of the representative values was calculated and put in tables.

To determine the air temperature, humidity and speed in the warehouse a portable thermo-anemometer type VT 300 produced by KIMO was used.

This device (Figure 1) has a display with automatic illumination and a screen size of 66x33mm, a shock resistance case manufactured from ABS/PC, with edges and buttons made of Elastomer. It is provided with four buttons and a rotary command button. The communication with computers is realized through RS 232 bus.

Fig. 2. *VT 300 portable thermo-anemometer* [7]

To the thermo-anemometer the following measurements instruments can be attached: the anemometer with chatterbox which uses a Hall effect sensor; the hot wire anemometer which uses a thermo resistance with negative temperature factor; the hygrometer with capacitive element; the PT 100 class A temperature probe; the K class 1 thermocouple; the optical tachometer; the contact tachometer. The alimentation is realized from four alkaline batteries of 1.5 V LR6, the working temperature of this device is situated between 0…50 °C

The measurements were effectuated by attaching one probe at a time which can register two different parameters simultaneously. So, for temperature determination at the surface and inside the potatoes Thermocouple penetration probe type SFP-K (Figure 3) was used.

Fig. 3. *Thermocouple penetration probe type SFP-K* [7]

For the temperature and the speed of the air flow which is introduced by the mechanical ventilation system inside the warehouse through the holes from the perforated floor the anemometer type LV 107 (Figure 4) which uses a Hall Effect sensor was used.

The working principle for this kind of anemometer is the following: the rotation of the shaft of vane powers a circular magnet of 8 poles (Figure 5). A dual Hall Effect sensor, placed next to the magnet senses the signals of magnetic field polarity transition.

The sensor signal is converted into electrical frequency and is proportional to the air velocity. Signal chronology allows the detection of rotation direction.

Fig. 4. *Anemometer type LV 107* [7]

Also the walls, the floor and the ceiling temperatures were measured with a thermometer which measures the temperature in infrared type KIRAY 200 (Figure 6), produced by the French firm KIMO.

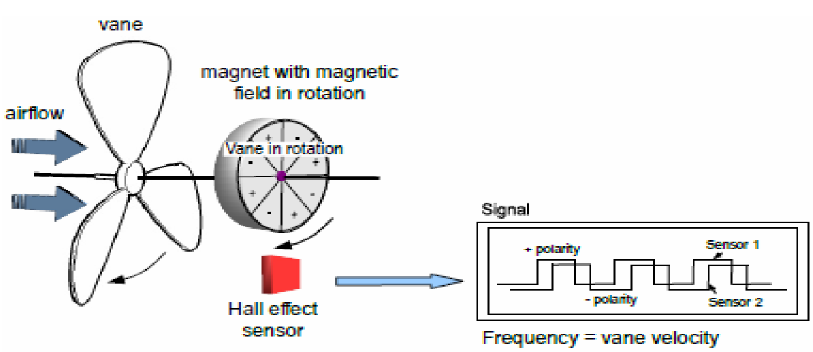

Fig. 5. *Anemometer type LV 107 working principle* [7]

Fig. 6. *KIRAY 200 infrared termometer* [7]

This device has a spectral response between 8…14 μm and it has a time response under a second. It can measure temperatures between −50 °C…+850 °C with an accuracy of: ±5 °C from the displayed value in −50 °C…−20 °C interval; ±2 °C ±1.5% from the displayed value in −20 °C…+200 °C interval; ±2 °C ±2% from the displayed value in 200 °C…+538 °C interval; ±5°C ±3.5% from the displayed value in 538 °C…850 °C interval. The display resolution is of 0.1 °C.

In the case of potatoes internal and external temperature measurement there were chosen 10 potatoes of 5 varieties. The potatoes where taken from different heights, respectively from the floor level, from 1 m and 2 m heights. Also, in this case, the measured peaks which represented the measurement errors were eliminated and then the average of the remained values was calculated. These values were written in tables.

For measuring the air flow speed in the ventilation holes there was a waiting of 3 minutes for: the ventilation cycle to be made completely, the electrical engine of the fan to reach the nominal speed; the air temperature of the introduced air flow to be the real one and not the one existing in the ducts before the engine starts.

3. Results and Discussions

The measured data were systematized and inserted into Table 2 and Table 3. To have a centralized situation the parameters which were measured were written in a simplified manner and their significance was explained afterwards.

Table 2

Measured parameters in mechanical ventilated warehouse in three different days

Measured Parameter	**14.12.2010**			**20.01.2011**			**23.02.2011**		
	***Temp.,* [°C]**	***Hum.,* [%]**	***Air S* [m/s]**	***Temp.,* [°C]**	***Hum.,* [%]**	***Air S* [m/s]**	***Temp.,* [°C]**	***Hum.,* [%]**	***Air S* [m/s]**
I.W.	4.2	80	0	4.7	78	0	4.1	76	0
E.W.	0.7	84	5	1.4	84	3	2.2	65	3
I.O.V.N	3.7	-	1.4	3.5	-	1.6	3.7	-	1.3
II.O.V.N	3.9	-	1.3	3.7	-	1.1	3.7	-	1.1
III.O.V.N	3.9	-	1.1	4.2	-	1	4	-	0.9
IV.O.V.N	4	-	0.6	4.3	-	0.7	4.1	-	0.7
I.O.V.F	4	72.5		4.6	84		3.4	69	
II.O.V.F	4.1	75.4		4.4	82		3.6	68.9	
III.O.V.F	4.4	71.8		4.4	80.3		3.5	74	
IV.O.V.F	5.6	65		4	78		3.8	76	

In Table 2 the notations have the following signification: *I.W.* is the warehouse interior; *E.W* - the warehouse exterior; *I.V.H.N* - the first ventilation hole near the fan when the engine is not working; *II.V.H.N* - the ventilation hole placed at ½ form the warehouse length when the engine is not working; *III.V.H.N* - the ventilation hole placed at ¾ form the warehouse length when the engine is not working; *IV.V.H.N* - the last ventilation hole when the engine is not working; *I.V.H.W* - the first ventilation hole near the fan when the engine is working; *II.V.H.W* - the ventilation hole placed at ½ form the warehouse length when the engine is working; *III.V.H.W* - the ventilation hole placed at ¾ form the warehouse length when the engine is working; *IV.V.H.W* - the last ventilation hole when the engine is working; *Temp* - measured air temperature, in ^{o}C; *Hum* - measured air humidity, in %; *Air S* - air flow speed, in m/s.

Walls and potatoes varieties measured temperatures Table 3

Measured Parameter	**14.12.2010**		**20.01.2011**		**23.02.2011**	
	***T.In*, [^{o}C]**	***T.Ex*, [^{o}C]**	***T.In*, [^{o}C]**	***T.Ex*, [^{o}C]**	***T.In*, [^{o}C]**	***T.Ex*, [^{o}C]**
N	-	3.1	-	2	-	1.9
S	-	2.6	-	1.7	-	2
V	-	3.2	-	1.5	-	2
E	-	2.3	-	2	-	2.3
F	-	4.2	-	2.3	-	2.7
C	-	4.7	-	1.2	-	2.2
P.O.	3.7	3.9	3.2	4.2	2.7	4.2
P.C.	3.3	4.0	3.2	4.7	2.1	2.9
P.T.	3.7	4.1	3.7	4.7	2.2	3.2
P.A.	3.7	4.4	3.7	3.1	2.2	3.2
P.R.	3.7	4.1	3.2	4.2	2.6	3.2

In Table 3 the notations have the following signification: *N* - is the warehouse northern wall, which is also the warehouse length. This wall is common with the southern wall of another warehouse; *S* - the warehouse southern wall, which is also the warehouse length. This is an exterior wall; *E* - the warehouse Eastern wall, which is also the warehouse width. This is an exterior wall; *V* - the warehouse Western wall, which is also the warehouse width. This is an exterior wall and on which the access door is placed; *F* - the warehouse floor; *C* - the warehouse ceiling; *P.O.* - Ostara variety potatoes; *P.C* - Christian variety potatoes; *P.T.* - Tampa variety potatoes; *P.A.* - Alize variety potatoes; *P.R.* - Rustic variety potatoes; *T. In* - the internal temperature, in ^{o}C; *T. Ex* - the surface temperature, in ^{o}C.

From Table 2 and Table 3 it can be observed that, although the exterior temperature had varied during those three days, the temperature inside the warehouse remained constant in the potatoes optimal storage interval. Also, the interior humidity varied little and it wasn't influenced by the exterior humidity, because due to the low exterior temperatures the air ventilation was executed occasionally, only during day time and for short periods of time.

Having in mind that the floor holes used for ventilation are connected to the warehouse exterior, a passive ventilation air ventilation is made due to the air temperature pressure difference. For this reason the measurements inside the ventilation holes have great importance, because these can perturb the inside climatic factors and also the potatoes storage period. It is observed that temperatures inside the ventilation holes when the fan is stopped are appropriated by warehouse interior temperatures because these holes are underground and the air is brought to soil temperature through the thermal radiation phenomenon.

From measurements it is observed that the potatoes' internal temperature, regardless of the variety, decreases easily during storage almost to frost limit, although their surface temperature is close to the one inside the warehouse. For this reason it is recommended that before their removal from the warehouse, to be moved inside a cell in which their internal temperature to be raised.

The warehouse walls' different temperatures are given by its placement in terrain (cardinal points) or the common wall with another warehouse. For a minimal perturbation given by the walls thermal transfer is recommended that when a warehouse is constructed, to determine the cardinal points and if is possible to construct the warehouse width in the less favorable point and even make it common with other constructions.

The speed of the airflow which is introduced form the exterior is decreasing linear with the distance to which the ventilation holes are placed. That is why in the case of warehouses that use only mechanical ventilation, the stored potatoes must not be placed near the first 2-3 ventilation holes because the risk of freezing appears [4].

As it can be observed, the ceiling temperature is smaller than the floor and the walls temperature which means that through this point the highest heat loss occurs, this construction element thus causing the most important perturbation. It is important that in these cases the ceiling be supplementary isolated and lowered.

The major disadvantage of warehouses that have only mechanical ventilation is that the humidity inside the warehouse is not constant and varies even with 15%. This interval is even larger when spring days come because the outside humidity becomes smaller and smaller and when the ventilation system is started, air with humidity even by 40% lower than the optimal one is introduced inside.

4. Conclusions

1. In warehouses' construction it is important for the northern wall to represent the warehouse width and if this is not possible it must be supplementary isolated. Also, the ceiling must be taken into account because through this area the hot air is eliminated.
2. Due to the potatoes' internal temperature which drops during storage, before their removal from the warehouse, it is recommended to raise the temperature slowly to avoid potatoes' internal injury, because the internal temperature is lower than the exterior surface temperature.
3. In case of temperature variation as it was in the period between 2010 December - 2011 February, a warehouse without climatic factors automatic control, would assure a quasi constant temperature and humidity if situated in the potatoes optimal storage interval, so for this period a automatic control system for temperature and humidity adjustment is not impetuously necessary.

4. From the measurements that were made at the National Institute of Research and Development for Potato and Sugar Beet from Braşov Romania, in a warehouse without automatic control systems for climatic factors, it results that Ostara and Rustic potatoes varieties are the most suitable for long storage because their internal temperature does not vary so much as compared to the other varieties of potatoes that were measured. So when the managers are designing the storage strategy it is recommendable for them to have in mind that the potato varieties mentioned above are suitable for a long term storage and the other potato varieties that are mentioned to be sent to markets as soon as possible.

Acknowledgements

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), POSDRU/88/ 1.5/S/59321 financed from the European Social Fund and by the Romanian Government.

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