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The simplified method of determining internal volume of bean pods

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Summary. The study includes the results of research on developing a simplified method of determining air volume inside a pod. The research has been performed on bean pods cultivated for dry seeds of the varieties Narew, Nida, Warta and Wawelska. Ten methods of determining volume have been compared (pycnometric and nine simple models of a pod).

The volumes determined by the method 1 (pycnometer) and method 7 were the most approximate and they were not statistically significant between themselves. It may be stated that the proposed simple model of a pod measurement makes it easier to determine the air volume inside the pod.

Key words: bean pod, volume, measurement methods.

INTRODUCTION

In cultivation of leguminous plants, a significant problem is i.a. susceptibility to cracking their pods and falling seeds. Susceptibility to cracking bean pods is shown by falling seeds during harvesting as a result of action of the working sets of harvesting machines, mainly various devices of cutting and trimming plants, gatherers and landing nets [5, 9]. The tendency of pods to burst open is conditioned by the content and structure of fibre in pod walls and their seams, which is a variety-related feature and depends on meteorological conditions during vegetation [3, 6, 8, 10, 14, 17].

In order to test the influence of various determinants on the susceptibility to cracking fruits of this plant, it is necessary to develop a method allowing its precise measurement. One of the methods of the susceptibility of pods to cracking is a pressure method [16]. It relies on forcing, to the inside of the pod, by means of the injection needle, of compressed air and measurement of the pressure at which there is breaking of its stitches. The measurement of the susceptibility of pods to cracking is the calculation of energy of bean pod opening [12, 13], for which the knowledge of not only the cracking pressure (relatively easy to be measured) is required, but also of the air volume in the pod. The second factor, due to an irregular shape of this kind of fruit, relies on the difficul measurement. Strobel [2003] defines the volume of air in a pod is as a difference of approximate volume and the volume of its seed. The approximate volume of a pod is calculated as the volume of a cylinder with the height equal to its length and diameter being arithmetic mean of pod width and thickness in its medium part.

Precise volumes of bodies with irregular shapes may be determined by a pycnometer, however, it is time consuming and requires relatively great work effort arising from the necessity of performing measurements for the entire pod and then for seeds and shells.

The aim of the work was an attempt to develop simplified methods of developing air volume inside bean pods.

MATERIAL AND METHODS

The research was carried out in 2008-2010. The bean was cultivated in the experimental field of the Department of Engineering in Agricultural Food Production in Rzeszów. The research was conducted on pods of bean cultivated on dry seeds of varieties: Narew, Nida, Warta and Wawelska which were characterized by varied seed and pod size (Tab. 1). Pod dimensions were calculated using an electronic slide calliper with the accuracy of 0.01 mm. Length was measured from the beginning of stalk to the peak, and width and thickness in cutting plane of perpendicular to main axis of the fruit, leading through its centre.

Table 1. Pod characteristics (average values) of the tested bean varieties

Specification	Narew	Nida	Warta	Wawelska
Dimension of pods [mm]:				
Length	93,2 a	91,1 a	105,9 b	113,8 c
Width	10,1 b	10,2 b	9,8 a	10,9 c
Thickness	9,4 c	9,1 b	8,8 a	9,6 c
Number of seeds in pod	4,7 d	4,1 b	4,4 c	3,8 a

* different letters in line signify significant differences, as per LSD test (significance level of $\alpha = 0.05$)

The measurement of breaking pods was performed with the pressure method relying on forcing compressed air to a pod and measurement of pressure at the moment of breaking along stitches. The obtained value is the energy of bean pod opening. Thus the energy required to open a pod was calculated with the pressure method [11, 13, 16], which is based on tearing a pod by compressed air, from the relation:

$$E = \frac{3}{2} pV, \tag{1}$$

where:
E – energy of bean pods opening [J],
p – air pressure in the pod [Pa],
V – air volume inside the pod [m^3].

There has been a comparison of exact determination of air volume inside a pod by a pycnometeric method [2] and nine simplified methods (simple models of a pod). In the method 1, air volume in a pod was determined as a difference of total volume of a pod and volume of seeds inside and volume of its shells determined by a pycnometric method according to the formula:

$$V_a = V_p - V_s - V_c, \tag{2}$$

where:
V_a – volume of the air in a pod,
V_p – volume of pod,
V_s – volume of seeds in a pod,
V_c – volume of pod coats.

In order to avoid moistening the pods, which would influence the values of pressure needed for their opening, water has been replaced with the powder ''Dry Flo". This method allows for exact determination of pressure volume inside the pod, and at the same time determining the energy needed for its opening. It allows for proper differentiation of bean varieties due to the susceptibility of their pods to breaking and more exactly defining an influence of various factors on this property of pods. This manner of determining volume is very time and labour consuming. The obtained exact values of internal volume of pods filled by air were applied in developing a simple model of a pod, which allows determining air volume in a pod, and at the same time, defining the energy needed for its opening.

In the method 2, the volume of a pod is calculated as the volume of a cylinder with a height equal to its length and diameter being an arithmetic mean of pod width and thickness in its medium part:

$$V_{a2} = V_{cy} = 0{,}25\,\pi \cdot W \cdot T \cdot L, \tag{3}$$

where:
V_{a2} – volume of the air in a pod,
V_{cy} – volume of the cylinder,
W – width of the pod,
T – thickness of the pod,
L – length of the pod.

In the methods 3-9, air volume in the pod was calculated as the volume of a body which is complex in the central part of a cylinder ended with two cones:

$$V_{a3\text{-}9} = 2V_{co} + V_{cy} = \pi \cdot W \cdot T\,(0{,}17H_{co} + 0{,}25H_{cy}), \tag{4}$$

where:
$V_{a3\text{-}9}$ – volume of the air in a pod,
V_{cy} – volume of the cylinder,
V_{co} – volume of the cone,
H_{cy} – height of the cylinder,
H_{co} – height of the cone,
W – width of the pod,
T – thickness of the pod.

The section of the cylinder and the base of cones constituted an ellipsis as in the method 2. In the method 10, air volume in a pod was calculated as the volume of the body made of two cones connected by bases with a shape of an ellipsis:

$$V_{a10} = 2V_{co} = 0{,}17\,\pi \cdot W \cdot T \cdot H_{co}, \tag{5}$$

where:
V_{a10} – volume of the air in a pod,
V_{co} – volume of the cone,
H_{co} – height of the cone,
W – width of the pod,
T – thickness of the pod.

The heights of a cylinder and cones for these methods 3-10 are included in Table 2.

Table 2. Height of the cylinder and cone in models of bean pods in the methods 3-10 (L – length of pod)

Method	Height of the cylinder H_{cy}	Height of the cone H_{co}
3	0,75 L	0,125 L
4	0,5 L	0,25 L
5	0,4 L	0,3 L
6	0,3 L	0,35 L
7	0,25 L	0,375 L
8	0,2 L	0,4 L
9	0,1 L	0,45 L
10	0	0,5 L

The obtained results were statistically analyzed [1, 4, 7, 15] with Statistica 9 program, including variance analysis and LSD significance test.

RESULTS

On the basis of the variance analysis, significant differentiation of air volume values inside the pod were confirmed for the applied methods of determination. For the tested varieties, air volume in bean pods was determined with the method 7:

$$V_{a7} = 0{,}125 \cdot \pi \cdot W \cdot T \cdot L. \quad (6)$$

that was the most approximate for the one determined precisely by means of the method 1 (pycnometric), which was confirmed by the test NIR indicating the lack of significant differences between the values of the described feature determined by these methods (Tab.3). The variety of Nida constituted an exception, for which the most approximate air volume determined by the pycnometric methods was the volume determined by the method 6:

$$V_{a6} = 0{,}133 \cdot \pi \cdot W \cdot T \cdot L. \quad (7)$$

Air volumes determined by the method 6 were higher and by the method 8 lower than the ones determined with methods 1 and 7, however, there were not statistically significant differences.

Table 3. The air volume [cm^3] in the pods of tested bean varieties for the applied of methods of their determination

Methods	Varieties				Average
	Narew	Nida	Warta	Wawelska	
1	3,35 cd I	3,49 c I	3,57 cd I	4,52 cd II	3,73 cd
2	6,93 h I II	6,68 g I	7,18 h II	9,36 h III	7,52 h
3	5,78 g I	5,51 f I	5,99 g I	7,80 g II	6,27 g
4	4,62 f I	4,41 e I	4,79 f I	6,24 f II	5,01 f
5	4,16 e I	3,97 d I	4,31 e I	5,61 e II	4,51 e
6	3,69 d I	3,52 c I	3,82 d I	4,98 d II	4,00 d
7	3,46 cd I	3,30 c I	3,59 cd I	4,68 cd II	3,76 cd
8	3,25c I	3,09 c I	3,36 c I	4,38 c II	3,52 c
9	2,77 b I	2,64 b I	2,87 b I	3,74 b II	3,01 b
10	2,31 a I	2,20 a I	2,39 a I	3,12 a II	2,51 a

*different letters in columns and Roman numerals in line signify significant differences, as per LSD test (significance level of $\alpha = 0.05$)

The conducted analysis by means of the test NIR (Tab. 3) indicated that due to the air volume in a bean pod determined by the method 1, the variety of Wawelska was statistically different from others. The same differentiation between the varieties was obtained by other methods, apart from the method 2, which additionally significantly differentiated the varieties of Nida and Warta.

To sum up, it must be confirmed that the method 7 allows, in a simplified manner, to determine the air volume in bean pods.

CONCLUSIONS

1. Air volume inside the pod significantly depended on the variety and the methods of determination.
2. The most approximate air volumes in the analysed pods of bean varieties to the ones determined precisely by the method 1 (pycnometric) was calculated by the method 7.
3. Air volumes determined by the method 6 were higher and by the method 8 lower than the ones determined with methods 1 and 7, however, there were not statistically significant differences.

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UPROSZCZONA METODA WYZNACZANIA OBJĘTOŚCI WEWNĘTRZNEJ STRĄKÓW FASOLI

Streszczenie. Praca zawiera wyniki badań nad opracowaniem uproszczonej metody wyznaczania objętości powietrza wewnątrz strąka. Badania wykonano na strąkach fasoli uprawianej na suche nasiona odmian Narew, Nida, Warta i Wawelska. Porównano dziesięć metod wyznaczania objętości (piknometryczną i dziewięć prostych modeli strąka).

Objętości wyznaczone metodą 1 (piknometrem) i metodą 7 były najbardziej zbliżone i nie różniły się miedzy sobą statystycznie istotnie. Można więc uznać, że zaproponowany w tej metodzie prosty model strąka ułatwia wyznaczenie objętości powietrza w nim zawartego.
Słowa kluczowe: strąk fasoli, objętość, metody wyznaczania.

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