Experimental stand for studying the stretch behaviour of woven plastic nets used in the food industry

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Abstract. Mesh bags are the most modern way of packing, storing and transport used for packing vegetables and a variety of fruits. Mesh bags provide freshness, mechanical ventilation and offers a clear image of the content. Determination of elongation is one of the tests by which the nets used in the food industry must be done before their distribution. The mesh bags are made from recyclable materials, available in different colours and can be inserted into foil strips that provide ample space for images and product information. The products being analysed are polyethylene woven nets for packing vegetables (potatoes, onions, peppers, cabbage, carrots, cucumbers, etc.), fruits (apples, pears, oranges, lemons, nuts, etc.) in a diversified dimensional and coloristic form representing the cheapest and most accessible method of packaging. The authors had concerns in the field developing a series of stands with applications in the food industry.

1. Introduction
The nets for packing vegetables, fruits, toys and gifts, in a diversified range of dimensions and colour, represent the most modern and cheap packaging. The packaging made of extruded nets offers maximum visibility for food, at the same time allows the product to breathe and highlight its colour. Due to the great diversity of types of fruits and vegetables on the market, their shape and the need for personalized packaging, both in terms of weight and variety of products, the article aims to conduct a study for six types of food nets and the determination of the maximum elongation they can withstand until the moment of breaking (for example the packaging of products of the same caliber in the tubular net of citrus fruits or onions 3 or 4 each, bearing small loads 200-500 grams, or packing in the net tissue that closes with metal clips of fruits and vegetables (potatoes, onions, garlic, apples, citrus bearing loads between 0.5 - 5 Kg) [11]. The authors designed and executed an experimental stand (Figure 1) to determine the maximum elongation until the breaking of the food nets, the traction force being ensured by a high-performance Test-Stand-HV-500N equipment, produced by Hans-Schmidt, equipped with a graphical interface that allows the interpretation of results in the form of graphs.

Vegetable, fruit, toy and gift packaging nets are made of plastics, the method of production can be extruded nets or woven food nets. Usually woven mesh bags are used for packaging vegetables (onions, potatoes, carrots, celery, beets). red) in quantities between 5-25 Kg. The plastic is the material that contains as a main ingredient a high polymer, with high molecular weight and which at a certain stage of the transformation into a finished product can be formed by flow. During the transformation into a finished product, the plastic material is softened by subjecting it to temperature, pressure and mechanical stresses, finally obtaining products with a well-defined form and properties [1, 2, 10, 11].
Figure 1. Schematic representation of the experimental stand: 1 – counterweight; 2 – mobile stroller; 3 – food net; 4, 5 – pulleys.

Figure 2 shows the main forms of nets used to pack food products [12, 13, 14, 15].

Figure 2. Types of nets used in the food industry: a - woven tubular mesh; b - extruded mesh; c - different types of nets used in the food industry.

Table 1 shows how properties such as density, molecular weight, and molecular weight distribution influence the properties of the polymer and the finished product. In these cases, the final use is the one that dictates which assortment best suits this final purpose.
Table 1. Influence of the three basic molecular properties on the polymer

| Physical-chemical properties | If the density increases between 0.915 and 0.938 | If the average molecular mass increases | If the molecular mass distribution is narrowed |
|-----------------------------|-----------------------------------------------|----------------------------------------|-----------------------------------------------|
| Melt viscosity              | increase                                      | increase                                | insignificant increase                         |
| Vicat softening point       | significant increase                           | insignificant increase                  | insignificant increase                         |
| Yield strength              | significant increase                           | insignificant increase                  | insignificant increase                         |
| Tensile strength            | insignificant decrease                         | increase                                |                                                |
| Elongation at break         | decrease                                      | increase                                |                                                |
| Friction coefficient        | increase                                      |                                        |                                                |
| Bending module              | significant increase                           |                                        |                                                |
| Flexibility                 | decrease                                      | insignificant increase                  | increase                                      |
| Hardness                    | significant increase                           |                                        |                                                |
| Surface hardness            | increase                                      |                                        |                                                |
| Contraction                 | increase                                      | increase                                | increase                                      |
| Dimensional stability       | insignificant increase                         | increase                                |                                                |
| Impact resistance of the film | decrease                               | increase                                | insignificant increase                         |
| Cold resistance             | decrease                                      | insignificant increase                  |                                                |
| Tear resistance of the film | depends on the technology of obtaining the film | insignificant increase                  |                                                |

With increasing density properties such as: softening point (Vicat softening point), gas and water vapor permeability, transparency and clarity of the film are improved, but properties such as: flexibility and shock resistance are disadvantaged. This choice may be favorable for packing consumer goods and less for packing vegetables and fruits that require superior resistance to shock and breakage. The increase of the average molecular mass confers good properties for the processing in the form of packages, which in turn must be resistant to the action of the various agents in the environment, or subject to the action of various liquids, solvents, detergents and oils. A high density polyethylene packaging will withstand much better handling and action of detergents, solvents, acids. If the viscosity in the melt decreases with the increase of the average molecular mass, these types of polyethylene are processed harder and require higher processing temperatures. Polyethylene with low molecular weight distribution is best suited to obtain products with increased resistance to the action of external agents and resistance to cold. The relationships between the three basic molecular

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properties are often influenced by other structural properties of the polymer molecule. The properties of the finished product and therefore of the polymer are changed during the processing process [9].

2. Device design and execution
The experimental stand (Figure 3 and Figure 4) was designed with the help of the SolidWorks CAD program, which is designed on an extremely simple, reliable and friendly architecture. SolidWorks includes all the major features of a software package for computer-aided design. It has its own geometric core, with the integrated drawing module. The modeling strategy has as a starting point the design based on the constructive-technological characteristics of the parts, continuing with the realization of the assemblies, the functional dimensioning and the semi-automatic generation of the execution drawings [3, 4, 5, 6].

![Figure 3. Catching net device: a, b – general view; c – detail](image1)

![Figure 4. Details of device for testing nets in the food field: a - detail of the pulley system; b - counter weight system; c - carriage mount detail](image2)
The execution technology comprised the steps of the metal frame made of 20 mm side profiles assembled by welding with a WIG installation and the parts of the sheet shown in figure 5 were processed by means of laser cutting [8]. Figure 6 presents the final experimental stand.

Figure 5. Experimental stand for testing nets in the food field:

a – trolley subassembly: 1 – guide bar; 2 – guide rollers; 3 – trolley; 4 – metal frame; 5 – food packaging net fixing bar; 6 – pulley;
b – counterweight subassembly: 1 – counterweight; 2 – metal frame; 3 – pulley.

Figure 6. Final assembly experimental stand
3. Experimental results
The experimental research aimed to determine the approximate elongation for six types of nets, using a Hans-Schmidt force transducer, Test-Stand-HV-500N, the maximum value of the force being determined by the force transducer.

**Figure 7.** Determining the elongation of the feed nets before and after loading with traction force

The approximate elongations were determined for six types of nets used for the transport of fruits and vegetables (Figure 7), each type of mesh was weighed using an electronic scale (Figure 8), the values being presented in table 2.

**Table 2.** Weighing the tested nets

| Mesh   | Weight (g) |
|--------|------------|
| Mesh 1 | 4          |
| Mesh 2 | 1          |
| Mesh 3 | 3          |
| Mesh 4 | 1          |
| Mesh 5 | 1          |
| Mesh 6 | 2          |

**Figure 8.** Weighing of first net
The equipment with which the tensile strength was measured is vertical manual test stand (Test Stand HV-500N – Figure 9) with a manual action for measuring different types of loads with maximum measured forces that can reach 500 N [7]. Figure 10, 11 and 12 presents the nets during the experiment.

**Figure 9.** Test Stand HV-500N [7]

|   |   |
|---|---|
| ![Mesh 1 before stretching](image1) | ![Mesh 1 after stretching](image2) |
| ![Mesh 2 before stretching](image3) | ![Mesh 2 after stretching](image4) |

**Figure 10.** Testing the first two types of nets
Figure 1. Stretch testing of nets on the realised stand
Figure 12. General view of realised stand for testing the nets used in the food industry: 1 - device for testing nets for the food field; 2 - tested net; 3 - carriage; 4 - 3D printed pulley; 5 - pulling wire; 6 - Test Stand HV 500

Figure 13. Force in function of time for mesh 1

Figure 14. Force in function of time for mesh 2
Figures 13-18 show the results of the traction force as a function of time for the 6 different types of nets tested. In order to be able to compare the results, the diagram from Figure 19 was made where it can be seen that at the net 5 the highest forces of almost 18 N are obtained, and the net 1 results with the lowest forces - below 8 N.
The first net, being thicker and having a longer elongation so a high elasticity, can be successfully used as a net for tree protection, trunk ventilation and light passage, the structure of the net is resistant to moisture, frost, for example such a net can be used to pack fir trees.

Nets 2, 3, 6 with less elongation can be used for packaging fruits and vegetables, fresh products (grapes, cherries) packaging for gifts, toys, cosmetics. The advantages of these packing nets are: they allow the aeration of the product; eliminates condensation; are adapted to any size; highlight the colour of the packaged product; the packaging process is very simple. Nets 4, 5 resisting higher tensile forces, can cover larger quantities between 3 - 25 Kg. An example of use can be packing potatoes, carrots, beets.

![Figure 18. Force in function of time for mesh 6](image)

![Figure 19. Graph of the maximum traction force for the 6 tested nets](image)

4. Conclusions
Determining the elongation of the nets is one of the tests by which the nets must do them before distributing them to suppliers. Mesh bags are made of recyclable materials, available in different
colors and can be inserted foil strips that provide ample space for images and product information. The products that are analyzed are woven polyethylene nets for packing vegetables (potatoes, onions, peppers, donuts, cabbage, carrots, cucumbers), fruits (apples, pears, oranges, lemons, nuts, etc.) in a diversified dimensionally and coloristically form representing the cheapest and most accessible packaging. For example, a net used to pack fir trees must have a longer elongation than that used to pack fruits or vegetables.

In order to achieve a civilized trade, fruits and vegetables must be packed so as to be protected and properly labeled, the materials used to make the packaging must not cause changes in the characteristics of fruits and vegetables, distribute the weight evenly to be durable and to be recycled. Knowing the elongation of the nets is a determining factor in choosing the right type of net in order to control the amount of food or other packaging material.

5. References
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