
USING SUNFLOWER SEED HUSKS WASTE FOR SUSTAINABLE THERMAL ISOLATING COATINGS

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ABSTRACT

The paper presents experimental results of the research carried out in order to obtain an innovative finishing/protection product for plasterboard surfaces, using sunflower seed husks, waste generated by the edible oils industry. In the form of an addition consisting of one or two-dimensional fractions, sunflower seed hulls have been incorporated into a finishing/protective coating product, the latter acting as a binder. The multilayered application of the resulting products, on gypsum board surfaces, led to a coating having good adhesion to the support as well as good thermal insulation characteristics (between 0.165 W/m.K and 0.095W/m.K), despite the small thicknesses of the coating (between 3.15 mm and 5.10 mm) compared to the traditional products with thermal insulating properties.

Keywords: vegetable waste; finishing; thermal insulation; multilayered system.

REZUMAT

Lucrarea prezintă rezultate experimentale ale cercetărilor efectuate în vederea obținerii unui produs inovator de finisare/protecție a suprafețelor de gips carton, prin utilizarea de coji de semințe de floarea-soarelui, deșeu generat de industria uleiurilor comestibile. Sub forma unui adaos alcătuit din una sau două fracțiuni dimensionale, cojile de semințe de floarea-soarelui au fost înglobate într-un produs peliculogen de finisare / protecție, ultimul având rol de liant. Aplicarea în sistem multistrat a produselor rezultate, pe suprafețe de gips-carton, a condus la obținerea unor acoperiri cu o bună aderență la suport precum și cu bune caracteristici de izolare termică (între 0,165 W/m.K și 0,095W/m.K), în ciuda grosimilor mici ale acoperirii (între 3,15 mm și 5,10 mm) comparativ cu produsele tradiționale cu proprietăți termoizolatoare.

Cuvinte cheie: deșeu vegetal; finisaj; izolare termică; sistem multistrat.

1. INTRODUCTION

Globally, the percentage of husk in sunflower seeds represents 21.1% - 29.8% of the seed production [1], [2], so that sunflower oil producers face with large waste stocks, a similar situation being at the national level, too.

In Romania, in the last 3-4 years [3], [4], [5] the agricultural production of sunflower had an upward trend; it is satisfying to know that it is processed in the country, and not exported as raw material. However, this is also generating a significant amount of specific plant waste. Therefore, several units producing

edible sunflower oils are interested in new ways to integrating this vegetable byproduct in the economy. The development of a superior way to use these products could reduce the waste and may contribute to diversifying the economy and source of profit, generating more jobs.

According to Directive 2009/28/EC [6], Article 2(e), and to Decision 216/2017 [7], Article 7, biomass is "the biodegradable fraction of products, waste and residues of biological origin from agriculture (including plant and animal substances), forestry and related industries, including fisheries and

aquaculture, as well as the biodegradable fraction of industrial and municipal waste”.

Biomass is a term that refers to the mass of substance generated by the development of living organisms. It includes agricultural products, waste from agriculture or from the processing of agricultural crops, residues from the production of sugar, starch etc. Biomass consists of 88 ÷ 99.9% of organic compounds, the main ones being cellulose and lignin.

The complex recovery of plant biomass has become a topic of global interest, with the depletion of raw material resources, taking into account that annual plants offer opportunities for recovery in many areas.

The introduction of the concept of "sustainability" in the construction design process encouraged the research that aimed at developing thermal and acoustic insulation materials to use natural or recycled materials. There is a lot of research that present the positive effects of introducing fibers or seeds of natural materials from plants into the production process of classical materials, leading to improved mechanical, thermal or acoustic characteristics.

On the one hand, currently, synthetic petrochemical products (polystyrene) or products obtained from natural sources (glass wool or mineral wool) are generally used to make thermal insulation of buildings, but manufacturing processes require high energy consumption, causing significant harmful effects on the environment.

On the other hand, it is known that cellulose forms the supporting parts of plants together with lignin and other non-cellulosic

substances and gives them elasticity. Because cellulose is organized into microfibrils, their structure is giving the plant rigidity and a porous nature favorable to the circulation of water, minerals and other nutrients [8].

After wood, annuals are the second major source of raw material for making pulp, so some of them (cotton, flax, hemp) are the main raw material resources for the textile industry, and are also used in the manufacture of certain types of paper.

Lignin is a component of wood, the second one after cellulose, and is the main constituent of the cell wall, the role of this substance being to ensure its strength. Lower plants (e.g. algae, lichens, fungi) do not contain this substance and in higher plants the lignin content varies widely, depending on the species and age of the plant tissue, for example being between 28 ÷ 34% in conifers, and between 18 ÷ 27% in deciduous trees [9].

Table 1 presents data published by the National Institute of Statistics on crop production in main crops in 2013 [10] which shows that annual and in particular technical plants give yields per hectare comparable or higher than wood, and the amount of fiber that can be obtained varies between 30 ÷ 50% of the plant mass.

Bio-composite materials used in the insulation process for residential and infrastructure buildings, as an alternative to petroleum-based materials, are new, sustainable materials that represent solutions to reduce carbon dioxide emissions and generate economic opportunities for the agricultural sector and not only for that.

Table 1. *The potential and main characteristics of cellulosic fibers of plant species in Romania*

Source of cellulosic fibers	Average production per hectare, (tons / year)	Amount of fiber* (tons / year)	Cellulose content, (%)	Lignin content, (%)	Average fiber length, (mm)
Flax	6,0	3,00	60-68	8-10	33,0
Hemp	15,0	6,70	57-77	9-13	25,0
Poplar wood	12,0	5,00	46-50	16-24	1,00
Rapeseed	3,5	1,40	40-45	8-13	1,80
Reed	10,0	4,00	44-46	20-24	1,20
Spruce wood	3,5	1,60	50-57	27-33	3,30
Sunflower stems	8,0	3,20	33-42	5-8	1,10
Sunflower seed husks **			34	22	
Wheat straw	2,0	0,80	34-40	16-21	1,50

* Average amount of cellulosic fibers per hectare (yield 40 ÷ 50%), tons/year

** (11)

According to C107/0-2002 [12], in order to be considered as a thermal insulation, a material must be characterized by a calculated thermal conductivity less than or at most equal to 0.10 W/m.K. Table 2 shows a comparison between the thermal conductivity of the different thermal insulation materials, values which highlight the aspects presented above [9].

Table 2. Comparison between the thermal conductivity of some materials

Type of thermal insulation material	Thermal conductivity, (W/mK)
Fiberglass mineral wool	0,044
Basalt mineral wool	0,042
Expanded polystyrene	0,045
Lignocellulosic fibers	0,037
Extruded polystyrene	0,034
Polyurethane foam	0,023

The studies and researches provided by the specialized literature have the role of supporting the real potential of capitalization of different vegetal culture materials, respectively of the afferent wastes, including the sunflower seed husks, at obtaining new, innovative, high-performance materials to be used in constructions.

This paper presents experimental results, obtained within the activity of the researchers from NIRD URBAN-INCERC, for the recovery of waste from sunflower seed husks resulting from the edible oils industry, capitalization materialized by obtaining innovative finishing / protection coatings for gypsum-cardboard surfaces

2. EXPERIMENTAL RESEARCH. MATERIALS AND METHODS

The method of capitalization of this type of vegetable waste consists in its incorporation, as an addition, in a film-forming finishing / protection material, the latter having a role of a binder. The aim was to obtain an innovative material whose workability would allow its application, in a multilayer system, on gypsum-cardboard surfaces, being determined the total thickness

and adhesion of the coating to the substrate. Subsequently, the thermal insulation character of the multilayer systems resulting from the application of the innovative material on gypsum-cardboard surfaces was tested.

Using one or two dimensional fractions of the mentioned vegetable waste, namely $\varnothing 4$ mm and $\varnothing 6$ mm, several basic recipes were developed, varying the following elements: the fraction of the waste incorporated (as a single fraction), the number of fractions used (one and two fractions, respectively) and the total amount of waste incorporated in each recipe. A constant amount (noted with A grams) of a single binder (noted with RM), based on acrylic resin was used, and the addition quantities (multiples of 1.25 and 1.50 respectively of the quantity B of vegetable waste of sunflower seeds husks) were established during the experimental work.

The aim was to study the effect that the mentioned compositional factors had on obtaining mixtures with a good workability and applicability on the plasterboard surface. The products that were obtained and their basic recipes are shown in Table 3.

Table 3. Basic notations and recipes of the obtained products

Product notation	Basic recipe of the product
RMb	A g RM+1,5B g $\varnothing 4$
RMc	A g RM+1,5B g $\varnothing 6$
RMd	A g RM+(1,25B g $\varnothing 4$ +1,25B g $\varnothing 6$)

The products RMb, RMc and RMd were applied on gypsum boards, after the surfaces were treated with a primer noted with "a", consisting of the binder RM and waste $\varnothing 4$ mm, having the basic recipe 10 C g RM + 0.3 B g $\varnothing 4$, C being a multiplication factor. The systems consisted of:

- a primer layer, applied by brush;
- the first layer above the primer, from the product RMb, RMc, respectively RMd applied by brush, to increase the roughness of the surface – support;
- the last two layers, applied successively with a stainless steel trowel. The notations of the multilayer systems applied on plasterboard, their average total thicknesses

and their average adhesions to the substrate, compared to those of the control product RM applied in three layers (the first by brush and the other two, with the stainless steel trowel), are presented in table 4. It should be noted that

these average total thicknesses of the multilayer systems were obtained given that each layer was applied to the smallest thickness allowed by the workability of the product.

Table 4. Notations, average total thicknesses and average adhesions of multilayer systems applied on gypsum board, compared to the control system (RM product)

System notation	RM (control system, three-layered)	RMabbb	RMaccc	RMaddd
Thickness, mm	1,17	2,49	2,85	2,90
Adhesion, MPa	2,82	1,33	1,42	1,35

For the determination of the thermal insulation characteristics of the RMabbb, RMaccc and RMaddd multilayer systems, they were applied on gypsum boards with dimensions of 29.5 x 29.5 x 1.25 mm, maintaining the same application method specified above for the primer and each of the three layers of RM:waste type products (RMb, RMc, respectively RMd).

The total average thickness of the multilayer systems was determined according to SR EN ISO 2808:2020 [13], the adherence to the support, according SR EN ISO 4624:2016 [14] and the thermal insulation properties, according to SR EN 12667:2002 (15), SR EN 12664:2002 [16].

Considering the gypsum boards A1, A2 and A3 as control samples, uncovered, the multilayer systems applied on them were later marked with A1 + RMabbb, A2 + RMaccc and A3 + RMaddd.

Figures 1, 2 and 3 show the appearance of the coatings obtained by applying on plasterboard the above-mentioned multilayer systems.



Fig.1. RMabbb system



Fig. 2. RMaccc system



Fig. 3. RMaddd system

In order to determine the thermal conductivity of these three samples, the following steps were done:

1. Measuring the thermal resistance of the gypsum-board support without coatings, after reaching constant mass at 40°C in a Venticell 22 laboratory oven, with air taken at (23 ±2) C and (50±5)% relative humidity;

2. Determining the thermal resistance of the samples A1+RMabbb, A2+RMaccc and A3+RMaddd, after applying each system on both faces of the gypsum-board, followed by curing and conditioning the samples to reaching constant mass at 40°C;

3. Determining the thermal resistance and the equivalent thermal conductivity of the RMabbb, RMaccc and RMaddd coatings, using equations (1) and (2):

$$R_v = R_{vG} - R_G \left[\frac{m^2 K}{W} \right] \quad (1)$$

where: R_v – the thermal resistance of the coating layers; R_{vG} – thermal resistance of the gypsum board specimen coated on both sides with each tested product; R_G – thermal resistance of the gypsum board specimen;

$$\lambda_v = \frac{\delta_v}{R_v} \left[\frac{m^2 K}{W} \right] \quad (2)$$

where: λ_v – the thermal conductivity of the coating; δ_v – the thickness of the coating layers.

As required by the normative used in buildings, the values for the thermal resistance and further for the equivalent thermal

conductivity of the coatings λ_v were expressed at the standard reference temperature of 10°C.

The measurement of the thermal resistances for the analysis of the thermal transfer properties of the three protections was performed by the hot plate method, a steady-state measurement technique, having the advantage to return high degree accuracy results [15], [16].

3. EXPERIMENTAL RESULTS

The experimental results referring to the thermal resistance of the multi-layered coating R_v , thermal conductivity of the same coating applied on gypsum-board support λ_v , total medium thickness of each coated sample and also medium thickness of each system on one side of the sample are presented in Table 5.

Table 5. Thermal characteristics and thickness of the multilayered systems applied on plaster-board support

Sample notation	Total medium thickness of the sample, (mm)	Thickness of each coating on one side of the sample, (mm)	R_v , (m ² K/W)	λ_v , (W/m.K)
A1, A2, A3	12,50	-	0,062	0,202
A1+RMabbb	19,41	3,45	0,104	0,165
A2+RMaccc	20,26	3,88	1,113	0,152
A3+RMaddd	22,71	5,10	1,156	0,108

4. DISCUSSION

The analysis of Figures 1, 2 and 3, as well as the average values presented in Table 4 for the total thicknesses and adhesions of the multilayer coatings RM, RMabbb, RMaccc and RMaddd applied on gypsum board, show the following:

- The appearance of the coatings is more textured as the characteristic size of the waste fraction increases or as the number of embedded fractions increases;
- The average total thickness of the control three-layered system, without added waste, was 1.17 mm, a lower value than each of the four-layered systems with added waste. As expected, the thickness of the systems had an upward trend both with the increase of the characteristic size of the waste fraction

(RMabbb vs RMaccc) and with the increase of the amount of waste incorporated (RMabbb and RMaccc, compared to RMaddd);

- Adhesion to gypsum board, from 2.82 MPa for the control system, decreased with the addition of waste, ranging between 1.33 MPa and 1.42 MPa, having on the one hand a slight tendency to increase with increasing characteristic size of the fraction, (the same quantities of RM binder and addition being used), but also to decrease slightly with the increase of the total amount of waste (also added to the same quantity of RM binder).
- All the average values of adhesions to gypsum board for the multilayer systems obtained in the research presented above are higher than the threshold of 0.5 MPa indicated by the Romanian regulations in force for products that could be assimilated to a certain

extent to the type of coating obtained by incorporating vegetable waste in the film-forming binder (regulation GE 056-2013 [17], for film-forming finishes, and NE-001-1996, for thin wet plaster [18]). In this context, it results that the systems developed, tested and presented in this paper are finishing/protection coatings with good adhesion to the support.

- From the point of view of the thermal insulation characteristics of RMabbb, RMacc and RMadd coatings, the results obtained indicated that:

- Test pieces A1, A2 and A3 from the plasterboard have a typical behavior for a homogeneous material, without air inclusions. The thermal conductivities of the three specimens have practically the same value, which allows extrapolation to the entire plate.
- Each of the samples tested has specific characteristics of thermal protection materials, although the layer thicknesses are much smaller comparing to those of traditional materials;
- The thermal conductivities of the multilayer systems RMabbb, RMacc and RMadd applied on gypsum boards A1, A2 and A3 are better than the average value of the thermal conductivity characteristic for the material - support (0.202 W / m.K);
- The thermal insulation characteristics are directly and to a large extent influenced by the porous, aerated character of the RM binder: vegetal waste mixture and also by the average total thickness of the applied multilayer system.

The analysis of the thermal conductivity values of the tested multilayer systems shows that their thermal insulation properties are better the higher the characteristic size of the vegetal waste fraction (RMabbb vs RMacc), respectively the higher number of fractions and amount of waste (RMabbb and RMacc vs RMadd).

5. CONCLUSIONS

The main conclusions of the experimental research presented above are the following:

- Comparing to the control system, consisting of three layers of finishing product RM, the incorporation of the addition of vegetal waste of sunflower seed husks in the acrylic product noted with RM (binder) generated:

- an increase in the average total thickness from 3.44 mm to 5.10 mm for the multilayer system when applying the RM:waste mixture on plasterboard;
- a decrease in adhesion to drywall from 2.82 MPa, for the control system, to values between 1.33 MPa and 1.42 MPa for the systems with sunflower seed husks, values which characterize a finish with good adhesion to the support surface.

- For RM:waste multilayer systems, the thermal insulation properties were generated on the one hand by the thermal insulation character of the embedded vegetal waste, and on the other hand by the aerated, loose character of the RM:vegetal waste material.

- Each of the tested samples has specific characteristics of thermal protection materials, although the layer thicknesses were much smaller compared to traditional materials, an aspect underlined by the fact that the thermal conductivity of multilayer protections was better than that of gypsum boards on which they have been applied.

- The originality of the method presented above, of capitalizing, in a construction material, the waste of sunflower seed husks resulting from the edible oil producing industry, consists in:

- Simplicity of operations and low costs regarding any technological investments required to obtain finishing materials with such vegetal waste addition;
- The fact that, the quantities of vegetal waste of sunflower seed husks used to obtain such type of a finishing can be significant taking into account the category of the resulting material (coating), considering the high consumption of this

type of product in the construction materials market. The positive effects will be obvious, especially if the benefits of using this type of coating would be effectively mediated, outlining the contribution that this innovative finish provides to the thermal insulation performance of the material-support on which it is applied.

Under the conditions of an adequate management of this type of vegetal waste, the Romanian agriculture could ensure a special potential for the intensification of the preoccupations regarding the development of new or innovative construction materials with / based on sunflower seed husks.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support from the Ministry of Education and Research through the project PN 19 33 04 02: "Sustainable solutions to ensure the health and safety of population in concept of open innovation and environmental protection".

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