Sheep wool pellets: from agro-waste biomass to an organic soil improver

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BACKGROUND AND AIM OF THE RESEARCH

Sheep wool is an important source of nitrogen and its potential as an agricultural renewable and sustainable organic fertilizer is high. Wool can be applied into the soil after any contamination from harmful bacteria (e.g., Listeria monocytogenes and Salmonella spp.) is excluded (as defined by Regulation (EC) No 1069/2009 - laying down health rules as regards animal by-products and derived products, not intended for human consumption).
The application of sheep wool pellets into the soil can be a virtuous example of a circular bioeconomy process providing sheep wool with an added value, possible income for farmers and benefits for the environment.

In this work, wool which is rich in N (12% of dry material), was mixed to spruce sawdust at sawdust:wool ratios of at 2:1; 1:1 (v/v) to increase soil organic carbon.
Pellets were morphologically (diameter and length), chemically (content of the elements required for fertilization) and microbiologically (content of harmful bacteria) characterized.

Sheep wool has been tested as a fertilizer in various forms e.g., washed wool fibers, wool residues from industrial washing, hydrolyzed wool, with positive results on crop productions and soil moisture retention. Wool pellets are a viable alternative to commercial fertilizers for organic vegetable production as they showed very similar growth and mineral uptake as compared to commercial fertilizers.
In this study pellets were developed mixing wool and sawdust to increase the concentration of carbon in the soil and find an alternative use to sawdust biomass. We, thus, added spruce sawdust, characterized by a C:N ratio of 400:100, and leading to lower degradation rates and prolonged times of decay.

This research aimed at: ì) developing pellets made of greasy wool and sawdust; ìì) describing the physical and chemical characteristics of the resulting pellets for their technical and commercial use in the agricultural sector; ììì) assessing the inhibitory effect of the pelletizing process on the, microbiological load of the greasy wool. .

MATERIALS AND METHODS

Wool Agro-Waste Biomass and Spruce Sawdust

The wool was obtained from Pomarancina sheep breed at an experimental farm in Florence, Italy (43°78′48.7″ N and 11°22′20.0″ E);

Fine spruce sawdust was produced from virgin spruce wood; the sawdust particle size was determined using a programmed shaker equipped with a <0.25 mm sieve.

The moisture content of wool and sawdust was determined using a Kern DAB 100-3 moisture analyzer (Kern & Sohn Gmbh, Balingen, Germany.

The test PT-1 was performed using a mixture of sawdust and wool (ratio 1:1) and the tests PT-2 and PT-3 with a mixture of fine spruce sawdust (ratio 2:1). In the PT-3, the mixture with pre-cut wool was used.

Physical characterisation

The particle size was determined using a programmed shaker equipped with a set of sieves, (Control, Milan, Italy). A set of 7 sieves with square mesh side dimensions was used: 8.0 mm; 4.0 mm; 2.8 mm; 2.0 mm; 1.40 mm; 0.710 mm; and 0.425 mm.

The linear correlation analysis was applied to determine the relationship between Relative Humidity (%RH), and Moisture Content (MC, %) dynamic of the three types of pellets produced.

Microbiological investigation

The samples were subjected to a comprehensive microbiological investigation to assess health risks according to the UNI EN ISO quality standards

RESULTS

Figure 1. Cutting mill on the left and pellet machine at the center. Up on the right the matrices wool and sawdust. On the bottom right, an example of mixture (11) and pellets (11)

Figure 2. Pellets produced by the three tests PT-1 Ratio Spruce SawdustWool = 11; PT-2 Ratio Spruce SawdustWool = 21; and PT-3 Ratio Spruce Sawdust cut Wool = 21

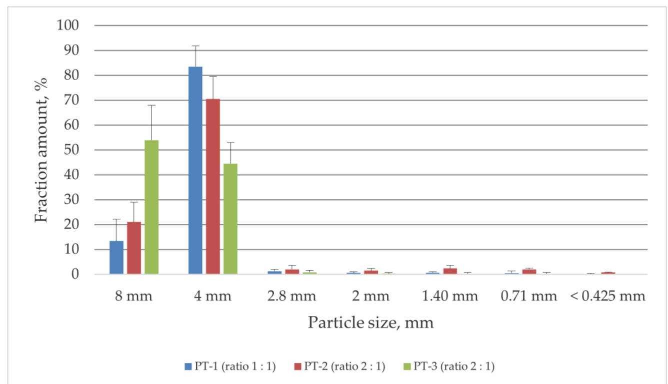

Figure 3. Particle size distribution of pellets.

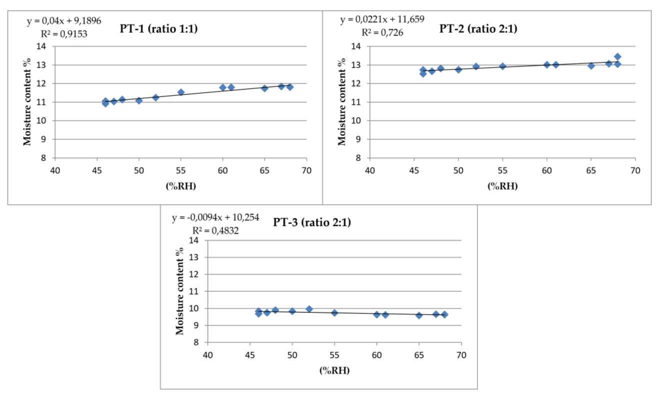

Figure 4. Statistical correlation between room Relative Humidity (%RH), and Moisture Content (MC%) dynamic of the three types of pellets oven-dried at 105 °C.

Items	PT-1 (ratio 1 : 1)	PT-2 (ratio 2 : 1)	PT-3 (ratio 2 : 1)	Mean	
	Mean (SE)	Mean (SE)	Mean (SE)		*p*-Value
DM, %	90.80	89.61	88.12	89.51	-
Bulk density (a.p.p), (Kg . m^{-3})	475.67 (12.89)	458.12 (13.22)	397.42 (16.90)	444.07	n.s.
1.000-pellets weight, g	464.14 (1.87) ^{b}	496.40 (1.08) ^{a}	501.05 (1.07) ^{a}	487.20	0.01
Proximal diameter, mm	3.64 (0.08)	3.70 (0.09)	3.82 (0.09)	3.72	n.s.
Distal diameter, mm	3.71 (0.10)	4.21 (0.09)	3.91 (0.09)	3.94	n.s.
Diameter, ratio	1.02 (0.41)	1.13 (0.13)	1.02 (0.01)	1.06	n.s.
Length, mm	17.06 ^{a} (0.71)	16.95 ^{a} (0.99)	20.87 ^{b} (0.99)	18.28	0.04

Table 1. Physical pellets characteristics.

Items	Wool	Mixture 1:1	Mixture 2:1	PT-1	PT-2	PT-3
Clostridium perfringens, CFU	<1.00 x 10^{1}	<1.50 x 10^{2}	<1.00 x 10^{1}	<1.00 x 10^{1}	<1.00 x 10^{1}	<1.00 x 10^{1}
E. coli beta-glucuronidase positive test, CFU	<1.00 x 10^{1}	<5.90 x 10^{2}	<5.70 x 10^{4}	<1.00 x 10^{1}	<1.00 x 10^{1}	<1.00 x 10^{1}
Listeria monocytogenes	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Total viable count (TVC), CFU	<3.20 x 10^{5}	<2.20 x 10^{4}	<1.20 x 10^{7}	<3.50 x 10^{3}	<1.00 x 10^{1}	<1.00 x 10^{1}
Salmonella spp., CFU	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Coagulase-positive *staphylococcus* (CPS), CFU	<1.00 x 10^{1}	<1.00 x 10^{1}	<1.00 x 10^{1}	<1.00 x 10^{1}	<1.00 x 10^{1}	<1.00 x 10^{1}

Table 2. Microbiological analysis (raw materials and pellets).

CONCLUSIONS

- The pellets can be used as an organic soil amendment in compliance with the DNSH (Do No Significant Harm) principle and can contribute to achieving the additional environmental objectives of the ecological transition (Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020).
- The characterization of the pellets provides preliminary information about the best combination of materials. Such information can be used in relation to both a commodity and an agricultural perspective.
- The results obtained from the analysis of the pellets show high content in total N and TOC and interesting dynamics of water retention. All of these factors can promote the use of pellets made of sawdust and greasy wool in crop production.
- Moreover, the profile of the pellets drawn in this work can contribute to highlight some features in terms of physical properties that, from a commodity point of view, could be useful in the future for the development of a technical textile product that meets both the demand of farmers in terms of handling and the logistic requirements in terms of transportation and storage.
- The drastic reduction in the content of harmful microorganisms in the pellets produced in this work in comparison with the microorganism load found in the raw materials proves that the pelletizing process used is a valid and feasible methodology to avoid the costly industrial wool scouring phase, which is required by law and regulations to use wool as an additive to the soil.

REFERENCES

Dal Prà, A.; Ugolini, F.; Negri, M.; Bortolu, S.; Duce, P.; Macci, C.; Lombardo, A.; Benedetti, M.; Brajon, G.; Guazzini, L.; et al. Wool Agro-Waste Biomass and Spruce Sawdust: Pellets as an Organic Soil Amendment. Sustainability 2024, 16, 2228. https://doi.org/10.3390/su16062228