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Co-Combustion Investigation of Wood Pellets Blended with FFP2 Masks: Analysis of the Ash Melting Temperature

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Abstract: The COVID-19 pandemic brought a period of high consumption of protective masks and an increase in their waste. Therefore, it was necessary to look at possibilities for their disposal. This article is focused on the disposal of FFP2 masks in the form of pellets blended with sawdust. Further, their ash melting behavior was observed. The method of ash preparation can impact the resulting values of melting temperatures. Therefore, this article investigates the resulting values of ash melting temperatures determined during different ash preparations, such as temperatures (550 °C and 815 °C) and ash size (non-sifted, smaller than 50 µm and 100 µm). All measured deformation temperatures were higher than 1100 °C and even higher than 1200 °C for some samples. Moreover, the presence of FFP2 masks in pellets only insignificantly affected the values of melting temperatures compared to pure wood pellets. The measured values also showed that increasing the temperature of ash preparation from 550 to 815 °C can increase the resulting values of melting temperature. The most significant proportion of the fraction size on the resulting melting temperatures was observed for beech with 5% and 10% of masks at an ash temperature of 550 °C and for spruce with 10% of masks at an ash temperature of 815 °C.

Keywords: COVID-19; disposal of masks; waste utilization; ash behavior; ash preparation; ash melting method

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1. Introduction

Over 146 million people have been infected and 3 million have died as a result of the COVID-19 pandemic [1,2]. Face masks have been used to reduce COVID-19 transfer from one person to another. Therefore, this protective equipment's global production and consumption have increased significantly [3]. As of 22 November 2020 [4], the amount of medical waste, comprising face masks, gloves, clothing, goggles, sanitizer, and disinfectant containers, imposed a 54,000 t/d environmental burden. Moreover, a lot of plastic waste, including COVID-19 protective equipment, has entered the ocean and endangered the natural marine system. Therefore, it was necessary to look at possibilities for how to dispose of them in an environmentally friendly way. One of the possibilities is their reuse in other processes.

Križan et al. [5] stated that energy from waste is a proven renewable energy technology. However, municipal waste is not in a suitable form for gasification, so it must be dried, shredded, disintegrated, and compacted into a suitable form such as briquettes or pellets. In this article, widespread FFP2 masks were processed by crushing and mixing devices into small pieces and blended with spruce and beech sawdust. Afterward, they presented input materials for pellet production, which can be further combusted without remarkable construction improvements. This way of disposing of face masks is described in this article by the production of two-component fuel. Further, the ash melting behavior was observed due to avoiding the agglomeration and other complications in connection with the possible combustion. In general, wood combustion has no problems with low melting temperatures if it does not contain bark or a large amount of other parts of the tree such as branches, roots, leaves, or needles. This often happens during the massive liquidation of wood stands, e.g., of wood chips, when all of the material is crushed together into one mixture. However, it is necessary to investigate these temperatures when additives and other materials are added to the wood. Moreover, ash melting temperatures can differ due to different ash preparation for these tests, as stated in the work of Čajová Kantová et al. [6]. The low melting point of the ash can cause various problems during combustion, starting with fuel metering problems when the formed ash slags block the transported fuel. Ash slags can also block the supply and proper redistribution of combustion air, resulting in lower combustion quality and producing more carbon monoxide (CO), organic gaseous hydrocarbons (OGCs), and particulate matter (PM). Finally, molten ash can stick to the heat exchange surfaces in the heat exchanger and thus significantly reduce the thermal efficiency of the heat source or cause corrosion [7]. In an extreme case, the heat exchanger can become completely blocked, and subsequently, it is necessary to stop the operation of the heat source, let the heat exchanger cool down, and clean it manually. In some cases, this process can take several days or even weeks [8]. For these reasons, it is critical to determine the ash's melting temperature and then take steps to mitigate these issues, such as using a suitable combustion method, co-combustion with other fuel, or adding additives.

Zapata et al. [9] stated that the ash sintering degree is related to composition and is dependent on the Si content. However, the increase in wood present in the agricultural blends did not cause their higher quality. These blends passed the combustion test despite the appearance of sintering and deposition phenomena. Royo et al. [10] added that the predominant deposition mechanism is by inertial impact in wood pellets, and by condensation in blend pellets with respect to deposition. Various previous work showed that this behavior of the blends can differ from that of single-parent fuels [11]. The ash melting behavior can be determined according to ISO 21404: 2020 [12]. Individual samples are prepared by ashing fuel at 550 °C or at alternative temperatures such as 710 °C and 815 °C. Atmospheric conditions can be used such as oxidizing with air or carbon dioxide and further reduced with a mixture of carbon monoxide and carbon dioxide or a mixture of hydrogen and carbon dioxide.

The preparation of ash should also be carried out by a mortar to ensure that it is as fine as possible. Too coarse a particle size could cause problems during the preparation of a usable test piece. However, the specific size of ash is not stated in this standard. Horák et al. [13] stated that ash crushing to a particle size smaller than 0.075 mm leads to an increase in specific surface area, surface energy, an increase in the frequency of defects in the crystal lattice, and an improvement in the contact between individual chemically diverse grains, which has a response in the behavior of the ash, which thus deviates from the conditions during real combustion. When the grains are spread, there is a substantial reduction in the temperatures at the beginning of sintering and the beginning of softening. However, data on ash size are missing in many studies. Link et al. [11] stated that the parent fuels (particle size ≤ 1 mm) were blended, but no data were provided about the size of the prepared ash.

Different ash preparation temperatures also often occur in many studies. Moreover, standard ISO 21404: 2020 [12] allows the use of alternative temperatures. However, it states that it can be difficult to detect the deformation temperature for some ashes produced at 550 °C due to the liberation of carbon dioxide from carbonates in the ashes, resulting in strong shrinkage of the test pieces. Ashing at a higher temperature removes carbonates from the ash, but also removes the possible content of low-melting salts. Horák et al. [7] used the following temperatures: 550 °C, 815 °C, and 975 °C for biomass species, coal, and paper sludge according to EN ISO 18122 for solid biofuels and ISO 1171 for solid mineral fuels. Du et al. [14] even used 450 °C, 600 °C, 815 °C, and 1000 °C as ashing temperatures. They investigated some inorganic component properties in biomass ash.

Reinmöller et al. [15] investigated ash fusion temperatures of ashes from hard coal, brown coal, and biomass under 815 °C and 450/550 °C. The lowest ash melting temperatures were attributed to the presence of low-temperature melting mixtures of several mineral phases, which formed a very fragile network.

The motive and novelty of this article is the energy recovery of relatively newly created waste from FPP2 masks. However, attention is mainly paid to the change in the ash melting temperature, which was obtained under different conditions. Fuel pellets were chosen, which were produced from spruce and beech sawdust blended with disintegrated FFP2 masks in the weight proportion of 5% and 10% or pure sawdust. The ash was prepared in a muffle furnace by ashing at 550 °C and 815 °C and then sifted through sieves. In this way, ash with a size smaller than 50 and 100 µm was obtained and further compared with its non-sifted sample. This article thus investigates and compares the resulting values of ash melting temperatures determined during different ash preparation such as temperatures (550 °C and 815 °C) and ash size (non-sifted, smaller than 50 µm, and smaller than 100 µm). It is necessary to know the ash melting temperatures due to possible combustion processes. However, the method of ash preparation is also very important to know and should be stated together with the values of the melting temperatures.

2. Materials and Methods

The input materials for pellet production were the following wastes: FFP2 masks from their production and sawdust from wood cutting. FFP2 mask waste is made of various polymeric materials, such as polypropylene and polystyrene. These masks were disintegrated by crushing and mixing devices into the forms of small pieces, approximately 0.5–5 mm. The size of both types of sawdust was in the range of 1–6 mm. After this, FFP2 masks were blended with spruce and beech sawdust by 5% and 10% of their weight proportion. FFP2 masks were added as an additive to avoid disruption of the pelleting process. The pellets created with 5% and 10% of mask contents still present wood pellets as fuel for heat sources for the combustion of wood pellets. Moreover, more heat would be released with a higher content of FFP2 masks, and classic heat sources are not constructed for this. Pellets created with a lower mask content do not require any adjustment to the combustion process with respect to ash and emission content. In the case of the use of higher-content FFP2 masks, these would be alternative pellets requiring special combustion.

The input materials were mixed together in the mixing device. A pre-weighed sawdust sample was put into this device at first, and then disintegrated FFP2 masks were also weighed and added. It took ten minutes to add the masks to the sawdust. Afterward, the created blend was mixed for another ten minutes. The blended material was compressed by a small pellet press with a power of 7.5 kW. The homogeneity was also ensured by the movement of a roller on a matrix of the pelletizer, which provided further mixing of the input material. The individual samples are stated in Table 1.

Table 1. Created pellets.

Sample	Weight Proportion Spruce Sawdust (%)	Weight Proportion Beech Sawdust (%)	Weight Proportion Face Masks FFP2 (%)
S100	100	0	0
S95	95	0	5
S90	90	0	10
B100	0	100	0
B95	0	95	5
B90	0	90	10

The air-drying process was used for the sawdust. The sawdust was distributed in the laboratory for two weeks in an indoor environment with the following controlled atmosphere: a temperature of 20 °C and a relative humidity of 40%. The FFP2 masks were placed in the laboratory under the same conditions as the sawdust. The created pellets, shown in Figure 1, with the same diameter of 6 mm, were stored in the laboratory for two weeks, ready for ash melting tests. They were stored at a temperature of 20 °C with a relative humidity of 40%.

Figure 1. Selected formed pellets: (**a**) S90, (**b**) B90.

The pure spruce pellets had a carbon content of 47.34%. The spruce pellets containing 5% of the mask material had an approximately 2.43% higher carbon content, and those containing 10% of the mask material had an approximately 4.03% higher carbon content than the pure spruce pellets. The hydrogen content was in the range of 6.14%–6.68% and the sulfur content was in the range of 0.03%–0.04% without the impact of the mask content. The nitrogen content was not detected. The pure spruce pellets had a lower calorific value of 17.59 MJ/kg. The spruce pellets containing 5% mask material had an approximately 1.38% higher calorific value, and with 10% of mask material, this value was approximately 2.36% higher than the pure spruce pellets. The ash content was in the range of 0.52%–0.85% without the impact of the mask content. The pure beech pellets had a carbon content of 45.90%. The beech pellets with 5% mask material had an approximately 2.94% higher carbon content, and those of 10% mask material had a 5.07% higher carbon content than the pure beech pellets. The hydrogen content was in the range of 6.64%–7.04% and the sulfur content was in the range of 0.03%–0.05% without the impact of the mask content. The nitrogen content was not detected. The pure beech pellets had a lower calorific value of 16.86 MJ/kg. The beech pellets containing 5% of the mask material had an approximately 1.29% higher calorific value, and those with 10% mask material were approximately 2.92% higher than for the pure beech pellets. The ash content was in the range of 1.0%–1.6% without the impact of the mask content.

The ash from the created pellets was obtained in a muffle furnace, according to ISO 21404:2020 [12], in two ways. The first way consisted of raising the temperature to 250 °C for 45 min and maintaining this for 120 min, and then increasing the temperature again to 550 °C and maintaining this for 240 min. The second way consisted of raising the temperature to 500 °C for 60 min and maintaining this for 30 min, and then raising temperature again to 815 °C for 60 min and holding it there for 150 min.

The ash prepared in this way was further sifted through sieves using the Retsch AS200 vibrating sieve equipment. Individual sieves with mesh sizes of 50 µm and 100 µm were put on top of each other. Ash with a size smaller than 50 µm and 100 µm was obtained by sieving and was further compared with the non-sifted sample. It was further connected by Dextrin drops into the ash paste, which was then formed into pyramids. These pyramids represented test specimens and were investigated by the ash fusion analyzer LECO AF 700, as shown in Figure 2.

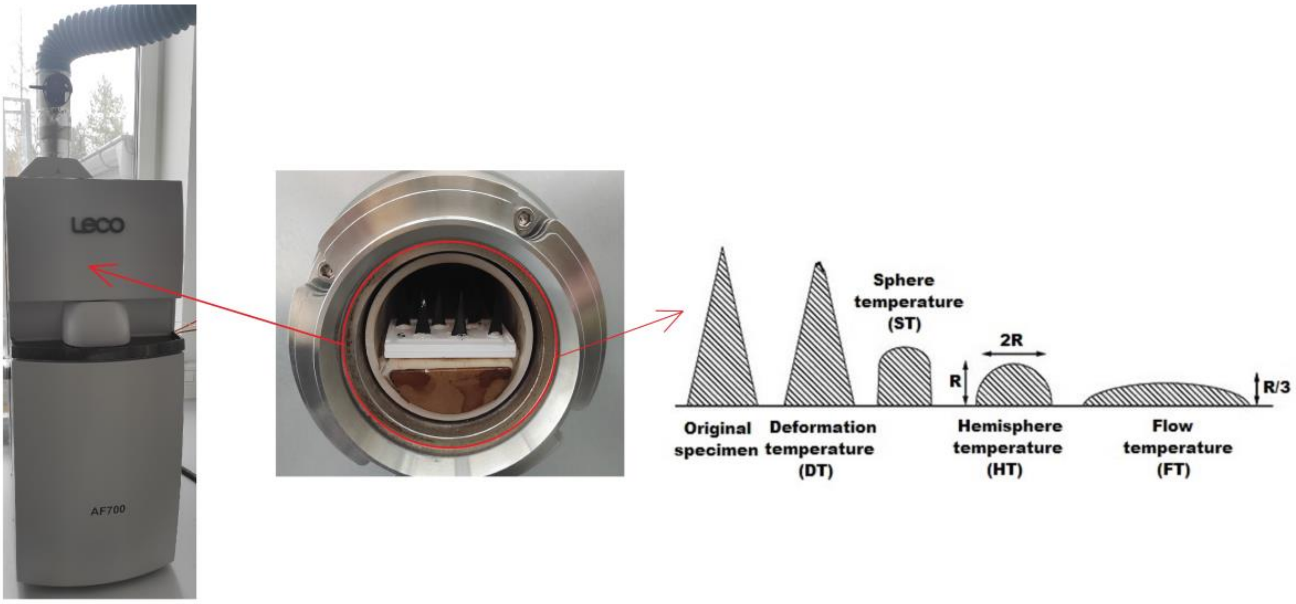

Figure 2. Ash melting analysis.

The specimens were heated up to 1500 °C, and the melting temperatures were observed based on the recorded images. The resulting ash melting temperatures are stated as: deformation temperature (DT), sphere temperature (ST), hemisphere temperature (HT), and flow temperature (FT). A normal atmospheric air composition was used as oxidizing conditions during the ash melting tests. These conditions are similar to combustion conditions in heat sources. Some samples had non-standard behavior, for example, due to insufficient gluing of the specimen into the ceramic pad. Such samples were excluded from the evaluation until three samples with standard behavior were obtained, from which two similar results were selected for the final evaluation. Therefore, the resulting values are their average values from two similar results with standard deviations, which were determined in the Microsoft Excel program.

3. Results and Discussion

The resulting values of individual ash melting temperatures were processed into figures and tables. Figure 3 shows the differences between the melting temperatures from ash prepared at 550 °C and fuel consisting of pure beech, beech blended with 5% of FFP2 masks, and beech blended with 10% of FFP2 masks. The obtained results showed a significant proportion of the fraction size on the resulting melting temperatures for the beech samples at a temperature of 550 °C, mainly for beech samples containing 5% and 10% of the weight proportion of FFP2 masks. Beech pellets containing 5% of FFP2 masks exhibited very little difference between the samples smaller than 50 μm and 100 μm, except for temperature, known as DT. However, a higher difference appeared between these samples and the non-sifted samples. Higher differences were observed in the beech pellets containing 10% FFP2, mainly for the temperature known as DT. Significant differences were also observed for the ST and HT temperatures, mainly between samples smaller than 100 μm and the remaining samples. The least significant difference in deformation temperature was found for the pure beech samples. The presence of FFP2 masks in the beech pellets only had an insignificant effect on the values of the melting temperatures.

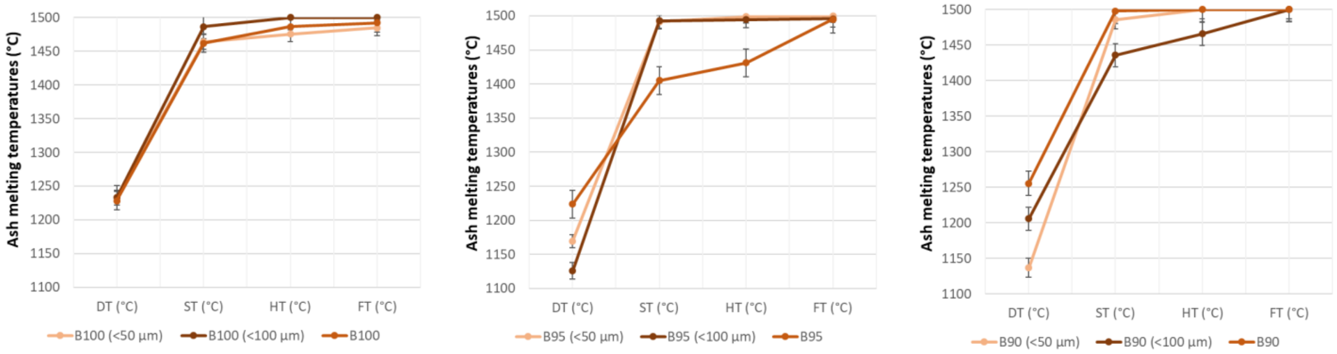

Figure 3. Differences in melting temperatures for beech samples prepared at 550 °C.

Figure 4 shows the differences between the melting temperatures from ash prepared at 550 °C and fuel consisting of pure spruce, spruce blended with 5% of FFP2 masks, and spruce blended with 10% of FFP2 masks. Compared to the beech samples, the results of the ash behavior of the spruce samples of ash at 550 °C showed little difference between the individual sieved and non-sifted samples. The highest differences were observed for the temperature known as DT for all spruce samples, but was the most significant for the pure spruce sample. Less significant differences were found in the deformation temperatures known as ST, HT, and FT for all spruce pellets. The presence of FFP2 masks in the spruce pellets only insignificantly affected the values of the melting temperatures.

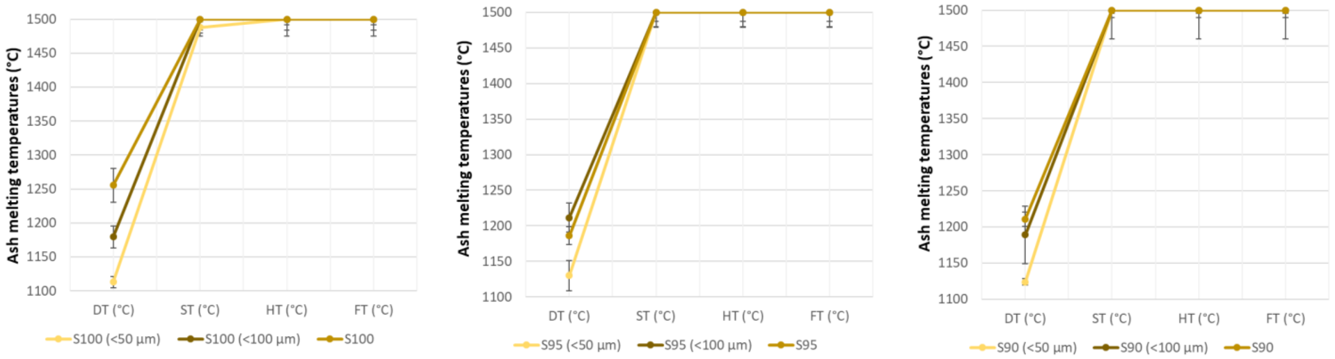

Figure 4. Differences in melting temperatures for spruce samples prepared at 550 °C.

Figure 5 shows differences between the melting temperatures from ash prepared at 815 °C and fuel consisting of pure beech, beech blended with 5% of FFP2 masks, and beech blended with 10% of FFP2 masks. The results of the beech ash samples produced at 815 °C again showed few differences in the ash behavior between the individual sieved and non-sifted samples, similar to the spruce samples prepared at 550 °C. The beech pellets had significantly smaller differences in the DT temperature. The presence of FFP2 masks in the beech pellets also only insignificantly affected the values of the melting temperatures in this case.

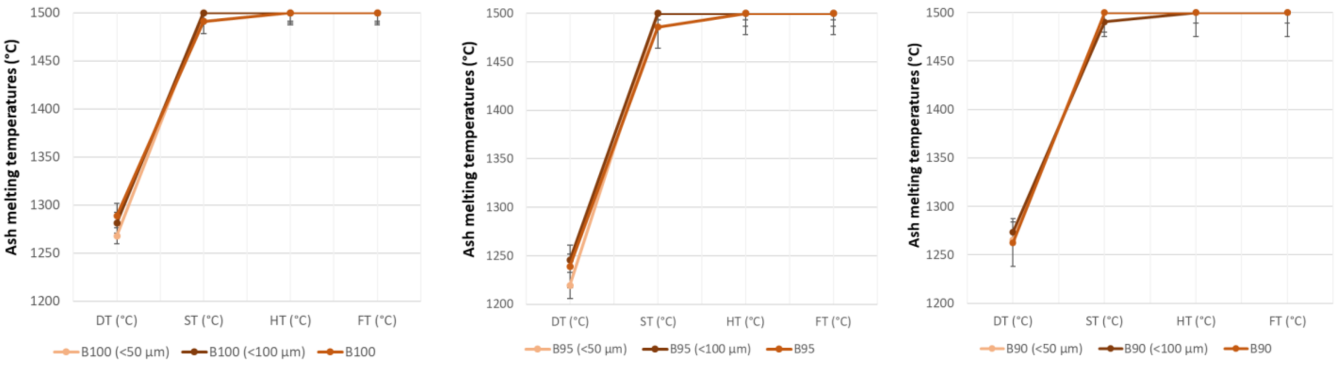

Figure 5. Differences in melting temperatures for beech samples prepared at 815 °C.

Figure 6 shows the differences between the melting temperatures from ash prepared at 815 °C and fuel consisting of pure spruce, spruce blended with 5% of FFP2 masks, and spruce blended with 10% of FFP2 masks. The results of the ash behavior of the spruce samples obtained at 815 °C showed the most significant difference in the spruce samples with 10% of FFP2 masks. The DT temperature of the non-sifted sample was similar to the sample smaller than 50 µm. However, a greater difference was observed between these samples and the sample smaller than 100 µm. The ST and HT temperatures had similar values for both sieved samples. However, a difference was observed between the sieved and non-sifted samples for these temperatures. The pure spruce samples and samples containing 5% FFP2 masks had similar values for the ST and HT temperatures. However, a significant difference was seen in both sieved and non-sifted samples for the temperature known as DT. The presence of FFP2 masks in the spruce pellets also only insignificantly affected the values of the melting temperatures in this case.

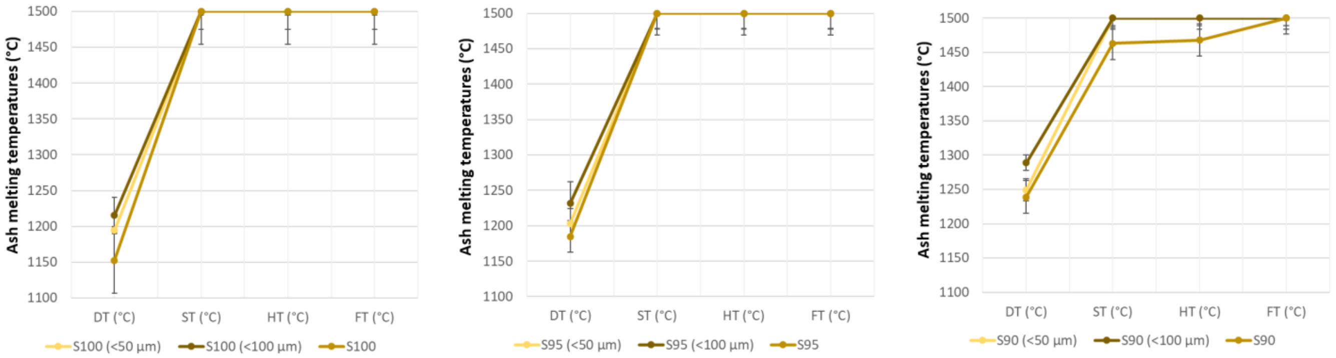

Figure 6. Differences in melting temperatures for spruce samples prepared at 815 °C.

The average values with standard deviations of the measured ash melting temperatures with ash prepared at 550 °C are stated in Table 2.

Table 2. Resulting values of ash melting temperatures prepared at 550 °C with their standard deviations.

Sample	DT (°C)	Standard Deviation (°C)	ST (°C)	Standard Deviation (°C)	HT (°C)	Standard Deviation (°C)	FT (°C)	Standard Deviation (°C)
B100 (<50 µm)	1233.0	4.2	1464.0	21.2	1475.5	7.8	1484.5	10.6
B95 (<50 µm)	1169.5	14.8	1491.5	12.0	1499.0	1.4	1500.0	0.0
B90 (<50 µm)	1137.0	22.6	1486.0	4.2	1500.0	0.0	1500.0	0.0
B100 (<100 µm)	1233.0	17.0	1486.5	19.1	1500.0	0.0	1500.0	0.0
B95 (<100 µm)	1126.0	25.5	1493.0	9.9	1494.5	7.8	1496.0	5.7
B90 (<100 µm)	1206.0	36.8	1436.0	5.7	1466.0	6.4	1500.0	0.0
B100	1228.5	10.6	1462.0	28.3	1486.5	2.1	1492.0	8.5
B95	1224.0	30.4	1405.0	10.6	1431.0	28.3	1495.0	12.0
B90	1255.7	31.2	1498.0	3.5	1500.0	0.0	1500.0	0.0
S100 (<50 µm)	1113.0	2.8	1488.0	8.5	1500.0	0.0	1500.0	0.0
S95 (<50 µm)	1130.0	21.2	1500.0	0.0	1500.0	0.0	1500.0	0.0
S90 (<50 µm)	1124.0	4.2	1500.0	0.0	1500.0	0.0	1500.0	0.0
S100 (<100 µm)	1179.5	16.3	1500.0	0.0	1500.0	0.0	1500.0	0.0
S95 (<100 µm)	1211.5	20.5	1500.0	0.0	1500.0	0.0	1500.0	0.0
S90 (<100 µm)	1189.0	39.6	1500.0	0.0	1500.0	0.0	1500.0	0.0
S100	1255.5	24.7	1500.0	0.0	1500.0	0.0	1500.0	0.0
S95	1186.0	12.7	1500.0	0.0	1500.0	0.0	1500.0	0.0
S90	1211.0	9.9	1500.0	0.0	1500.0	0.0	1500.0	0.0

Based on the measured results, it can be summarized that the melting temperature that differs the most is DT, and the other melting temperatures are more difficult to observe for woody materials because the ash melting analyzer only works up to 1500 °C. The lowest recorded DT was 1113 °C for the pure spruce sample, with the ash size smaller than 100 µm. The highest DT was almost 1256 °C for the non-sifted beech sample with 10% of FFP2 masks and also for the non-sifted pure spruce sample. All deformation temperatures were higher than 1100 °C and even higher than 1200 °C for some samples.

The average values with standard deviations of measured ash melting temperatures with ash prepared at 815 °C are stated in Table 3. The measured values showed that increasing the temperature of the ash preparation from 550 to 815 °C can increase the resulting values of ash melting temperature, mainly the value of DT. The lowest recorded DT was 1152.5 °C for the non-sifted pure spruce sample. The highest DT was 1289 °C for the non-sifted pure beech sample and for the spruce sample containing 10% FFP2 masks with an ash size smaller than 100 µm. All deformation temperatures were higher than 1100 °C and even higher than 1200 °C for some samples.

Van Loo and Koppejan [16] mentioned that spruce wood has the following ash melting temperatures: DT in the range from 1110 °C to 1340 °C; ST in the range from 1410 °C to 1640 °C; HT in the range from 1630 °C to 1700 °C; and FT higher than 1700 °C. Wang et al. [17] stated that spruce wood started to melt at around 1380 °C and was completely fused at around 1480 °C. However, the melting started at 1250 °C, and completely melted at 1378 °C with the addition of 10% bark. Horák et al. [13] stated the following ash melting values for wood chips determined in an oxidizing atmosphere according to ČSN ISO 540: 1290 °C for DT; 1410°C for ST; 1480 °C for HT; and 1490 °C for FT. The resulting values stated in this work are in accordance with the mentioned studies. The lower measured values of the ash melting temperatures could be caused by the presence of bark in spruce or beech, because the pellets were produced from the sawdust from wood cutting. In their article focused on the impact of bark content in wood pellets, Holubčík et al. [18] confirmed that the ash fusion temperature decreases with a higher bark content. However, Filbakk et al. [19] stated that no problems were observed with sintering when the bark content in pine pellets was low, namely, between 5 and 10%.

Table 3. Resulting values of ash melting temperatures prepared at 815 °C with their standard deviations.

Sample	DT (°C)	Standard Deviation (°C)	ST (°C)	Standard Deviation (°C)	HT (°C)	Standard Deviation (°C)	FT (°C)	Standard Deviation (°C)
B100 (<50 μm)	1268.0	8.5	1500.0	0.0	1500.0	0.0	1500.0	0.0
B95 (<50 μm)	1219.5	13.4	1500.0	0.0	1500.0	0.0	1500.0	0.0
B90 (<50 μm)	1265.0	4.2	1500.0	0.0	1500.0	0.0	1500.0	0.0
B100 (<100 μm)	1281.5	10.6	1500.0	0.0	1500.0	0.0	1500.0	0.0
B95 (<100 μm)	1245.5	6.4	1500.0	0.0	1500.0	0.0	1500.0	0.0
B90 (<100 μm)	1273.5	7.8	1490.5	13.4	1500.0	0.0	1500.0	0.0
B100	1289.0	12.7	1491.0	12.7	1500.0	0.0	1500.0	0.0
B95	1239.0	24.0	1486.0	19.8	1500.0	0.0	1500.0	0.0
B90	1262.5	24.7	1500.0	0.0	1500.0	0.0	1500.0	0.0
S100 (<50 μm)	1194.5	4.9	1500.0	0.0	1500.0	0.0	1500.0	0.0
S95 (<50 μm)	1203.0	21.2	1500.0	0.0	1500.0	0.0	1500.0	0.0
S90 (<50 μm)	1249.5	16.3	1500.0	0.0	1500.0	0.0	1500.0	0.0
S100 (<100 μm)	1215.5	24.7	1500.0	0.0	1500.0	0.0	1500.0	0.0
S95 (<100 μm)	1231.5	30.4	1500.0	0.0	1500.0	0.0	1500.0	0.0
S90 (<100 μm)	1289.0	11.3	1500.0	0.0	1500.0	0.0	1500.0	0.0
S100	1152.5	46.0	1500.0	0.0	1500.0	0.0	1500.0	0.0
S95	1185.0	22.4	1500.0	0.0	1500.0	0.0	1500.0	0.0
S90	1239.0	13.2	1463.0	30.1	1468.0	27.6	1500.0	0.0

Low ash melting temperatures can cause deposit formation, slagging, and sintering, which leads to problems during combustion. The formed sintering can also cause the blocking of airflow to the fuel layer [20,21]. In case of the need to increase the melting temperatures, mineral additives can be used. Kubica et al. [22] used kaolin as an additive for wheat straw combustion. The results showed that the application of mineral additives gave satisfactory results in terms of the increase in the ash-softening point. High-quality materials could be used in the manufacturing of the boiler parts exposed to a corrosive environment.

In general, wood biomass has higher melting temperatures than residual alternative biomass. The presence of FFP2 masks in all tested pellets only insignificantly affected the values of melting temperatures, in which the deformation temperatures were higher than 1100 °C and even higher than 1200 °C for some samples. Therefore, their presence in wood pellets should not cause the problems mentioned during their combustion. On the other hand, it is possible to expect a slight improvement in the combustion process due to a slight increase in the calorific value of the fuel. After the appropriate optimization of the combustion process by changing the amount and redistribution of the combustion air, it is possible to expect a slightly lower production of emissions, especially carbon monoxide, organic gaseous hydrocarbons, and solid pollutants—particulate matter. The advantage is that it is an ecological disposal of waste, because the pellets are still wood with only a small amount of waste that does not differ much from the standard. This means that the created pellets should not have a negative impact on their quality, combustion process, and emissions due to the chemical composition of the pellets. However, this requires more time-consuming experiments and analysis. Therefore, emission production is one of the issues of further research.

4. Conclusions

The method of ash preparation in ash melting tests can impact the resulting values of melting temperatures. This article thus investigated and compared the resulting values of ash melting temperatures determined during different ash preparations, such as temperatures (550 °C and 815 °C) and ash size (non-sifted, smaller than 50 μm and smaller than 100 μm). Except for that, it utilizes the waste produced in connection with the COVID-19 pandemic, with the main focus on FFP2 masks and their disposal in the form of pellets. The created pellets contained individual blends of spruce and beech sawdust with FFP2 masks in weight proportions of 5% and 10%.

All measured deformation temperatures were higher than 1100 °C and even higher than 1200 °C for some samples. Moreover, the presence of FFP2 masks in the pellets only insignificantly affected the values of the melting temperatures compared to pure wood pellets. Therefore, their combustion in heat sources could not cause problems with sintering and agglomeration. However, it is important to investigate the emissions that form during their combustion. The measured values showed that increasing the temperature of the ash preparation from 550 to 815 °C can increase the resulting values of the ash melting temperature, mainly the value of deformation temperature. However, the input wood material was taken from wood cutting, and thus the bark could be included as part of the pure wood in the pellets. In general, the ash fusion temperature decreases with the presence of bark in the fuel.

The obtained results showed a significant proportion of the fraction size on the resulting melting temperatures for the beech samples at an ash temperature of 550 °C, mainly for the beech samples containing 5% and 10% of the weight proportion of FFP2 masks. Specifically, a higher difference was observed the between sieved and non-sifted samples and also in the beech pellets containing 10% FFP2. Compared to the beech samples, the results of the ash behavior of the spruce samples at 550 °C showed little difference between the individual sieved and non-sifted samples. However, more significant differences were observed for the deformation temperature, mainly for the pure spruce samples. The results of the beech ash samples produced at 815 °C showed only a small difference in the ash behavior between the individual sieved and non-sifted samples. The results of the ash behavior of the spruce samples obtained at 815 °C showed a significant difference for the spruce samples containing 10% FFP2 masks at all melting temperatures. However, the differences were more obvious for the deformation temperature, and other melting temperatures are harder to observe for woody materials because the ash melting analyzer only works up to 1500 °C.

Based on these results, it can be confirmed that the ash preparation could impact the resulting values of the ash melting temperatures. The results can differ not only due to the temperature of the ash preparation, but also due to the ash size. It would be suitable to conduct more comprehensive research regarding several variants of the size of the prepared ash. However, it is necessary for specifying the ash preparation due to possible differences in the resulting values. Therefore, the conditions of ash preparation should be stated along with the resulting values of the melting temperatures.

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