Tampere University of Applied Sciences

Evaluation of composting process according to standard procedure of SFS-EN ISO 20200:2015 and SFS-EN ISO 20200:2023

Compost validity and analysis of odour and visual appearance

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ABSTRACT

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Compost validity and analysis of odour and visual appearance

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This thesis investigates the disintegration of nonwoven textile materials in a compost environment, focusing on the efficacy and suitability of the SFS-EN ISO 20200:2015 standard for conducting such tests. The study follows the prescribed methodology outlined in the standard, aiming to evaluate its validity and provide insights into odour and visual appearance analysis.

The research concludes that the disintegration test, conducted in accordance with the SFS-EN ISO 20200:2015 standard, yields successful outcomes. However, while the standard offers a robust framework, there is a need for refinement to achieve more detailed results. The investigation highlights the importance of analyzing odour and visual appearance of synthetic waste, emphasizing their role in enriching waste management practices.

While the standard serves as a solid foundation for initial assessments, further enhancements are necessary to ensure precision and comprehensiveness in test outcomes. Recommendations include refining methods and materials and placing a greater emphasis on odour and visual appearance analysis. These enhancements are essential for meeting evolving research needs and elevating the efficacy of waste management practices.

Key words: disintegration, nonwovens, hydrophobic, hydrophilic, odour and visual appearance, synthetic waste.

CONTENTS

ABBREVIATIONS AND TERMS

cr	credit
LOI	Loss on Ignition
TAMK	Tampere University of Applied Sciences
UHP	ultra-high purity

1 INTRODUCTION AND SCOPE

In the search for sustainable materials, the disintegration of nonwovens in compost environments emerges as a pivotal area of investigation. This thesis, entitled " Evaluation of composting process according to standard procedure of SFS-EN ISO 20200:2015 and SFS-EN ISO 20200:2023: Compost Validity and Analysis of Odour and Visual Appearance," dives into a study aimed at exploring the composability of hydrophobic and hydrophilic nonwoven materials under specific conditions. The project was commissioned by SUSTAFIT, a project that aims to replace unsustainable processes and materials with eco-friendly alternatives. It focuses on improving the sustainability, quality, and cost-effectiveness of nonwoven fabrics while expanding their applications. One goal of SUSTAFIT is to increase the market share of sustainable nonwoven fabrics. (SUSTAFIT.)

The research was conducted at Tampere University of Applied Sciences' environmental laboratory by Marita Hiipakka, Seija Haapamäki, Sara Di Giovanni, Robert Dascalu and Mamata Simkhada. One goal of this disintegration test is to highlight the need for sustainable waste management practices in industrial applications.

Nonwovens represent technologically advanced fabrics crafted from fibres, serving diverse purposes across consumer and industrial sectors. Tailored to meet needs, they span a spectrum from delicate and lightweight to robust and long-lasting variants, catering to various consumer and industrial needs. By carefully selecting raw materials, employing specific formation and bonding techniques, and applying finishing touches like printing or embossing, nonwovens achieve exceptional performance standards. (Edana.)

Nonwoven fabrics, characterized by their versatility and wide range of applications (from medical to geotextiles) pose significant environmental challenges at the end of their lifecycle. The distinction between hydrophobic and hydrophilic nonwovens adds a layer of complexity to their disposal and recycling processes.

Hydrophobic compounds exhibit minimal affinity towards water due to their predominantly nonpolar characteristics. They tend to form strong associations with nonpolar liquids like petroleum solvents. In contrast, hydrophilic substances strongly bond with water through hydrogen interactions, owing to their polar nature. Assessing the degree of hydrophobicity or hydrophilicity in a material can be accomplished by measuring the contact angle formed by water on the material surface in air. (Lag et al., 2008.)

This study's inception was motivated by the growing environmental concern over waste accumulation and the global push towards circular economies. The research hinges on the standard SFS:EN ISO 20200:2015, which outlines the criteria for determining the aerobic biodegradability of nonwoven materials in a controlled composting environment. This standard, along with its normative references, serves as the backbone of the methodology employed in this thesis, ensuring the reliability and validity of the disintegration tests conducted.

By examining the standard procedure of the disintegration of hydrophobic and hydrophilic nonwovens in a compost environment, this thesis aims to contribute insights into the composability of these materials. The assessment of compost validity, coupled with a detailed analysis of odour and visual appearance, provides a view of the environmental impact of nonwoven materials. The findings of this study could be used to inform industry practices, policy-making, and further research in the field of sustainable materials science. This thesis not only addresses a gap in literature but also aligns with the broader environmental objectives of reducing waste and promoting the use of compostable materials. Through an examination of the disintegration process, guided by the principles of standard SFS:EN ISO 20200:2015, this research offers practical solutions and theoretical contributions to the sustainable management of nonwoven materials.

The scope of this thesis is to evaluate the efficacy and suitability of the SFS:EN ISO 20200:2015 standard for disintegration tests on nonwovens in a compost environment, and the method validity and analysis of odour and visual appearance. The methods and procedures described in this thesis served to investigate the techniques for measuring odour and visual changes during the composting phase, analyses the physical disintegration patterns of the test samples, and examines the execution quality of the composting tests. Another aspect of the study is the examination of the R-value’s significance in validating test results, ensuring the research provides a thorough understanding of both the processes and the standards governing biodegradability assessments in compost settings.

2 MATERIALS AND METHODS

The test method according to the standard SFS-EN ISO 20200:2015 determines the degree of disintegration of plastic materials when exposed to a laboratory scale composting environment. It uses a standard and homogeneous synthetic solid waste with a consistent composition, free from any unwanted plastic material that could mistakenly be identified as test material after testing. This test method is not intended to assess the biodegradability of plastic materials in composting conditions and additional testing is required before claiming that a material is compostable. (SFS-EN ISO 20200:2015.)

There is an updated version of this standard (SFS-EN ISO 20200:2023) that was published on 12.9.2023, so some parts may differ from the older version, published in 2015. This disintegration test was done by the 2015 standard, the reason being that all the previous disintegration tests were done by the same version.

2.1 Preparation of the test

2.1.1 Sample preparation

In the TAMK environmental laboratory, the samples were cut into pieces with dimensions of 25 mm x 25 mm and around 20-30 grams per sample, in order to have enough for 3 replicates. To achieve constant mass, the cut pieces of material were dried at 40 ºC for 2 hours. For the constant mass procedure, the materials were placed on a glass plate large enough to avoid overlapping. They were then placed into a desiccator for at least 40 minutes and then weighed. This process was done at least three times or until a constant mass was reached.

Before putting the test material in the reactors, along with the synthetic waste, they were dipped into ion exchanged water for approximately 10 seconds. This was done by taking a few pieces at the time using a pair of tweezers. After the test materials have been soaked, they were taken out of the beaker and left to drip above the beaker, to remove any excess water.

2.1.2 Composition of the synthetic waste

The standard composition of synthetic compost provided by the standard SFS-EN ISO 20200:2015 was modified by using rapeseed oil instead of corn seen oil and table sugar instead of saccharose. The moisture content of each ingredient was researched and approximated, as the ingredients did not mention the moisture content. Through the percentage of moisture, grams of moisture were calculated, and the total moisture of the ingredients added up and removed from the water moisture content to reach 55% of total moisture of the synthetic compost. The materials used for making synthetic compost are shown in the table below, Table 1.

TABLE 1. Calculations for moisture content and mass of dry synthetic compost.

Material	Dry mass %	Total dry mass g/14 reactors	Dry mass g/reactor
sawdust	40	2520	180
rabbit feed	30	1890	135
ripe compost	10	630	45
corn starch	10	630	45
saccharose	5	315	22,5
seed oil	4	252	18
urea	1	63	4,5
			Total: 450

Materials used and their characteristics:

- Sawdust: Vene- ja puutyö Moilanen (untreated wood)
- Rabbit feed: Versele Laga Country's Best
- Compost: AhlmanEdu
- Corn starch: Maizena
- Sugar: Rainbow kidesokeri
- Rapeseed oil: K-Menu rapsiöljy
- Urea: Available in the environmental laboratory. Unknown brand and product number.

2.1.3 Description of the compost reactors

The compost reactors used were plastic boxes with approximate dimensions of 25cm x 20cm x 10cm and a plastic lid. The boxes had two small holes, one on each side, that were drilled to help with air flow.

2.1.4 Characteristics of the compost inoculum

The ripe compost inoculum was sourced from AhlmanEdu, Tampere. This 3,5-month-old inoculum consisted of farmyard compost made of hay, straw, cow manure and aged culturing media of Pleurotus ostreatus. The ripe compost inoculum was stored inside a formed animal shelter as an after-composting pile. The compost was in a stable condition, it did not generate heat and had a balanced pH. The inoculum emitted a fresh, earthy scent without any unpleasant odours, had a dark colour and it was damp with visible traces of straw or bulk material.

2.2 Starting the test

The synthetic waste was made in 14 separate buckets. Each component was weighed separately and added to each bucket. The composition was then mixed with a hand trowel in each bucket to try to maximize the homogeneity. If the synthetic waste were to be mixed in a very large container, it would result in a less homogenous mixture, thus it was made separately for each reactor. Three reactors for each test material were prepared so altogether 14 reactors with 4 different test materials including two reactors of original compost (synthetic waste without any test material).

After making the synthetic waste in each bucket, the mixture was transferred into the reactor box where each reactor box contained around 5 grams of test material. Each reactor box was labelled accordingly. Approximately 4 layers of synthetic waste and 3 layers of test material were used. The same process was applied to fill all the 12-reactor boxes with the test material. During the process of making this homogeneous layer, the mixture was not compressed to allow efficient gas exchange with the interior of the bed.

The reactor boxes filled with the synthetic compost mixture were weighed, closed with the tight sealed lid and placed in an air-circulation oven kept at a steady temperature of (58 ± 2°C) for a period ranging from at least 45 days to a maximum of 90 days. This process is known as thermophilic incubation period. To ensure a good composting process, it was necessary to maintain suitable environmental conditions. This process provides airflow to the composting material while keeping it adequately hydrated. The initial mass of the reactor containing the mixture was measured at the start of the composting process. At each scheduled interval, the reactor was weighed, and if necessary, the original mass was partially or fully restored by adding de-ionized water. It's crucial to understand that the ideal water level is achieved when the composting material is moist but not saturated with excess water. (SFS-EN ISO 20200:2015.)

The composting material was mixed using a laboratory spatula and a common spoon, taking care not to damage the test material pieces. This mixing was done to aerate the compost and redistribute the water while ensuring the test material pieces were not mechanically degraded. (SFS-EN ISO 20200:2015.)

2.3 Monitoring the composting process during the incubation period

2.3.1 Monitoring procedure

During monitoring days, the position of the reactor boxes was changed in the incubator in such a way, that samples series A, B, C and D were moved one level lower on the incubator shelves, whereas the reactor containing the sample Original-A was placed together with sample series A and the reactor containing the sample Original-B was placed together with sample series C. This way the reactors had a new position in the incubator every time. This procedure was done to make sure that the drying of the samples was constant since the heat produced in the incubator was coming from one source only. During monitoring days, the reactors were taken out of the incubators, they were weighed, and the moisture was restored if needed. Odour and visual appearance of the contents was also analysed, and the results were checked with the standard to make sure the disintegration process is going according to the standard. The contents of each reactor were mixed according to the standard. At the end of each monitoring phase, the reactors were turned 180 degrees and placed back in the incubator.

2.3.2 Photographing of test material

For the photographing procedure, grid papers were prepared for each sample series, containing the sample codes, date when the photographing was taken and days since the start of the testing. During the photographing phase, each reactor was opened, and test materials were extracted from the reactor onto the grid paper using a forceps. The test materials were handled carefully to avoid deterioration. This procedure was done to follow the process of disintegration of the samples throughout the test. The photographing procedure is one aspect that is not addressed in the SFS-EN ISO 20200:2015, nor in the SFS-EN ISO 20200:2023 standards, and it was done mainly to enhance the understanding of the evolution and variations in disintegration by gathering additional information. Additionally, it aimed to provide diverse perspectives on the results, which could prove valuable when conducting similar tests on a larger scale.

2.3.3 Temperature monitoring

A constant temperature of (58 ± 2) °C was maintained inside the incubator according to the thermophilic incubation period. Each day during the monitoring period, the temperature was checked if it is at (58 ± 2) °C or not.

2.3.4 Odour analysis

The odour of the synthetic compost was analysed on each monitoring day. The main idea was to observe the development in the odour of the samples and compare it with all the other ones.

In the first 3 to 5 days the synthetic waste should have a mild fermented odour, followed by a significant ammonia and chicken manure odour lasting for around 15 to 20 days. In the last 10 to 15 days of the test the synthetic compost should have a faint ammonia odour or no odour at all. Each time the samples were monitored, an excel sheet was prepared to record. (SFS-EN ISO 20200:2015.)

2.3.5 Visual inspection

The visual inspection of the contents was done on each monitoring day. The main idea was to see the development in the colour and texture of the synthetic waste and test material and compare it with the other samples.

In the first 5 to 7 days the synthetic compost should have a yellow colour, followed by a dark brown colour in the next 15 to 20 days. In the last days of the test, the synthetic compost should have a dark colour. Some traces of Mycelia could be seen on the synthetic compost and on the test materials throughout the test. Each time the samples were monitored, an excel sheet was prepared to record. (SFS-EN ISO 20200:2015.)

2.3.6 Moisture restoration

The moisture content of the wet waste was restored to its initial mass (100%, 80% and 70% depending on the stage of the process) during monitoring days, following the schedule of the test. The liquid used to restore the moisture content was ion exchange water. This was done by weighing each box individually, without a lid, and adding the desired amount of water, until initial mass was reached.

2.4 Terminating the disintegration test

At the end of the test, while still moist, the reactor boxes were taken out of the incubator, weighed without the lid and the contents were poured in small batches onto a plastic disk, in order to find any remaining test material. If any test material was found from the synthetic waste, it was carefully washed in a beaker containing tap water and left to dry overnight. After that, the dried test material was transferred onto a glass plate and put into a drying oven for 2 hours at 40 degrees Celsius. This procedure was done at least 3 times until reaching constant mass.

After this procedure was done for all reactor boxes, they were put back in the incubator without the lid at (58 ± 2) °C to dry and reach constant mass and later to be sieved following the standard procedure. The sieving was done using sieves approved by the standard ISO 3310-1, Test sieves. Each sample was sieved separately with 10mm, 5mm and 2mm sieves. The 3 fractions were stored in plastic grip bags and labelled. For the analysis done, only the fractions under 2mm were used, following the standard procedure.

2.5 Validity of the disintegration test

The chemical examination of the compost included various critical factors crucial for evaluating its effectiveness as a medium for nonwovens disintegration. To measure nitrogen levels, the Kjeldahl method was utilized, offering insights into the availability of nutrients within the compost, which indirectly affects the rate of microbial activity and decomposition. Furthermore, assessing the content of organic matter was achieved through the Loss on Ignition method, which measures dry mass and volatile solids, thus shedding light on the potential for microbial activity and the compost's overall stability.

The measurement of pH was also fundamental, providing an assessment of the compost's acidity or alkalinity levels, factors that influence microbial efficiency and the disintegration process of nonwovens. These chemical evaluations were crucial in determining the basic properties of the compost, affirming its appropriateness as a medium to support the breakdown of nonwovens in a compost setting. To ensure methodological rigor and adherence to established processes, the analyses of the compost were carried out in accordance with the standards SFS-EN ISO 20200:2015 and normative references included.

2.5.1 Determination of total nitrogen content by Kjeldahl analysis

For the Kjeldahl-N analysis, each of the dried samples, reduced to particles smaller than 2mm, was weighed and placed into digester tubes alongside 20ml of Sulfuric acid and 2 catalyst tablets. A total of 20 tubes were prepared for the analysis. These tubes were then left overnight in the digester to allow for adequate reaction time. The following day, before initiating the digestion process, the scrubber attached to the digester was activated, and the pH of the scrubber solution was measured. Subsequently, 2ml of mineral oil was introduced into each digester tube to mitigate foam formation during the process. The samples underwent preheating at 370 degrees Celsius for one hour, ensuring optimal conditions for subsequent digestion. Following preheating, the samples remained in the apparatus for an additional 2 hours at the same temperature, or until complete wet ashing was achieved, ensuring thorough combustion of all samples. After the 2-hour period elapsed, the digester was turned off, and the samples were left to cool for a minimum of one day before further processing. The samples were weighed using an analytical balance.

2.5.2 Titration

Before commencing the titration and distillation process, twenty 250 ml conical flasks were prepared, each containing 50 ml of boric acid solution and a small quantity of colour indicator. Additionally, 20 ml of ultra-high purity (UHP) water was added into each digester tube. The distiller and titrating apparatus were meticulously prepared, checked, and subjected to testing using blank samples to ensure the absence of any errors that might compromise the integrity of the analysis. Following the verification process, the cooled digester tubes were transferred to the distiller along with the conical flasks containing the boric acid solution. Approximately 100 ml of reagent was then added into each tube, and the distillation time was set to 4 minutes. Upon completion of the distillation period, the distilled liquid from the conical flasks was transferred to the titration apparatus, positioned on a stirring plate to facilitate thorough mixing. The titrant utilized in the titration process consisted of sulfuric acid with a concentration of 0.050M.

2.5.3 Dry mass

Crucibles with a constant mass were used to determine the dry mass of the synthetic waste. Samples with a size below 2mm were used for this analysis. The crucibles containing the synthetic waste were placed into a drying oven at 105 degrees Celsius for 2 hours, according to the standard.

2.5.4 Determination of the Loss on Ignition

The same crucibles used for the dry mass analysis, containing the same samples, were placed into an oven for 5 hours at 550 degrees Celsius, allowing them to burn properly. They were then transferred into desiccators to cool in a dry environment and weighed. The results and final calculations were registered and are shown in the results part.

2.5.5 pH- analysis

The pH measurement was conducted in accordance with the standard SFS-EN ISO 10390:2022. Samples smaller than 2 mm were measured using volumetric flasks. The measurement was performed volumetrically, making the weight irrelevant for this specific analysis. The primary criterion was to ensure that each sample reached a volume of 15 mL. Deionized water was added to the samples in a 1 to 5 ratio, which accounted to 75 ml. These jars were then placed on a stirring table, The samples were stirred for one hour and left to settle for an additional hour before the pH measurement was taken.

3 RESULTS

This chapter presents the results of comprehensive chemical analyses conducted on the compost samples, including Kjeldahl-N, dry mass, volatile solids achieved through the Loss on Ignition method, and pH-measurement, alongside the disintegration test outcomes, including disintegration of test material, the degree of disintegration and R-value. The analyses encompassed crucial parameters essential for assessing the compost suitability as a medium for the disintegration of nonwovens. Additionally, results regarding the odour and visual appearance of the synthetic waste are addressed in this chapter.

3.1 Results of chemical analysis

The titrant in sample is the amount of sulfuric acid used after distillation until the colour of the sample turned from light green to light brown. Titrant used in blank, along with titrant concentration were very important values since they were used to calculate and find the nitrogen percentage for each sample. The percentages of total nitrogen for the tested samples were quite close to each other, ranging between 0,60 to 2,00. The samples that were in the incubator for the whole duration of the test however do not have a total nitrogen percentage larger than 1,00.

An article available on Clemson University’s Public Service and Agriculture page stated that Total nitrogen in compost encompasses organic nitrogen, as well as ammonium and nitrate forms. Typically, the total nitrogen content in matured compost ranges from 0.5% to 2.5% on a dry mass basis. During the early stages of composting, ammonium levels can be elevated, but these levels generally decline as the compost reaches maturity. (Clemson.edu.)

From the pH-analysis, all the measured samples had a pH range between 7,00 and 7,90, except the two samples of original compost that were air dried, which had a pH of 5,60. The pH values though are in normal parameters. An article from Cornell University’s Waste Management Institute stated that microorganisms in compost thrive under conditions that range from neutral to slightly acidic, with optimal pH levels typically between 5.5 and 8. In the early decomposition phase, the formation of organic acids leads to acidic conditions, which support the proliferation of fungi and the degradation of substances like lignin and cellulose. As the composting process continues, these acids are neutralized, resulting in mature compost usually having a pH ranging from 6 to 8. (Cornell Waste Management Institute.)

The degree of disintegration was calculated for all three replicates according to the standard SFS-EN ISO 20200-2015. According to the standard SFS-EN ISO 20200-2015, the test is considered valid if the degree of disintegration does not differ by more than 20% across the three replicates of each test sample. In this case, 3 of the 4 test sample series disintegrated 100% on average, while one test sample had an average disintegration on more than 99%, therefore the test is considered valid from this point of view.

3.2 Characteristics and validity of the compost

All assessments of the validity were conducted on dried and sieved samples with a particle size below 2mm. The analysis used for monitoring the compost adheres to the methodologies specified in standards SFS EN ISO 20200:2015 and standards SFS-EN ISO 15934, SFS-EN ISO 15935:2021, SFS-EN ISO 16169, and SFS-EN ISO 10390:2005.

For a test to be considered valid, the reduction in R-value for total volatile-solids content from the initial synthetic waste to the compost at the end of the testing should be at least 30%. However, all reactors showed R-values below 30%, suggesting the composting process might not have been fully completed. Additionally, the carbon-to-nitrogen (C/N) ratio in all reactors exceeded 40:1, indicating a low total nitrogen content, which could also impact the composting process.

3.3 Results of odour and visual appearance

The odour and visual appearance of the synthetic waste was measured during monitoring days. The results are presented in the following tables, Table 2 and Table 3.

TABLE 2. Results of the odour analysis of the synthetic compost.

Odour	**Series A**	**Series B**	**Series C**	**Series D**	**Original compost**
0-1 days	fresh, sweet	fresh, sweet	fresh, sweet	fresh, sweet	fresh, sweet
1-3 days	mild, fermented	mild, fermented	mild, fermented	mild, fermented	mild, fermented
3-7 days	strong chicken/cow manure	strong chicken/cow manure	strong chicken/cow manure	strong chicken/cow manure	mild, fermented
7-25 days	strong ammonia	strong ammonia	strong ammonia	strong ammonia	mild ammonia
25-45 days	faint ammonia, pleasant	faint ammonia, pleasant	faint ammonia, pleasant	faint ammonia, pleasant	mild ammonia, sweet
45-60 days	weak ammonia/no odour at all	weak ammonia/no odour at all	weak ammonia/no odour at all	weak ammonia/no odour at all	weak ammonia/no odour at all

The results displayed in the table above represent an average of the replicates, as they exhibited consistent behaviour. Although the outcomes are slightly different from those outlined in the standard, they still adhere closely to the same pattern. The standard provides a broad overview, primarily focusing on significant changes that synthetic waste may undergo. In contrast, the results shown in the table above offer a more comprehensive assessment, going into finer details not covered by the standard analysis. This detailed evaluation enhances the understanding and of the changes in synthetic waste behaviour and aids in drawing better conclusions from the data.

TABLE 3. Results of the visual appearance analysis of the synthetic compost.

Visual appear-ance	Series A	Series B	Series C	Series D	Original compost
0-1 days	dry, yellow-light brown	dry, yellow-light brown	dry, yellow-light brown	dry, yellow-light brown	dry, yellow-light brown
1-3 days	dark yellow, some brown spots	dark yellow, some brown spots	dark yellow, some brown spots	dark yellow, some brown spots	dark yellow, some brown spots
3-7 days	dark brown colour, traces of mold	dark brown colour, traces of mold	dark brown colour, traces of mold	dark brown colour, traces of mold	dark brown colour, traces of mold
7-25 days	dark colour, significant amount of mold	dark colour, significant amount of mold	dark colour, significant amount of mold	dark colour, significant amount of mold	dark colour, significant amount of mold
25-45 days	dark colour, some dry spots, no mold	dark colour, some dry spots, no mold	dark colour, some dry spots, no mold	dark colour, some dry spots, no mold	dark colour, some dry spots, no mold
45-60 days	dark colour, significantly dry	dark colour, significantly dry	dark colour, significantly dry	dark colour, significantly dry	dark colour, significantly dry

The same ideas apply to the results regarding the visual appearance of the synthetic waste. The results represent an average the replicates since they showed similar behaviour. Again, the criteria provided by the standard does not go too much into detail and only gives a broad overview of the outcomes that should occur in a valid test. However, the results provided in the table above provide a more descriptive understanding of the changes in visual appearance of synthetic waste.

4 DISCUSSION

4.1 Challenges encountered during the disintegration test

The disintegration test for nonwoven materials was conducted successfully in accordance with the standard procedure outlined in the SFS-EN ISO 20200:2015 standard, along with its normative references and other relevant standards, including SFS-EN ISO 15934, SFS-EN ISO 15935:2021, SFS-EN ISO 16169, and SFS-EN ISO 10390:2005. However, certain adjustments were necessary as some aspects of the procedure were not explicitly defined or were entirely absent in the standards.

One notable challenge arose during the preparation phase of the disintegration test. The standard failed to provide clear instructions on how to cut the test materials, only specifying their required sizes. Consequently, a method involving folding the materials using a ruler and cutting them with scissors was employed. While this approach ensured adherence to the specified sizes, it proved time-consuming and occasionally resulted in unevenly cut pieces. Such discrepancies have the potential to impact the disintegration process and subsequent results, highlighting the need for standardized procedures in this aspect.

Additionally, the standard lacked guidance on the post-test handling of synthetic waste following chemical analysis. For this disintegration test, the synthetic waste was sieved and stored in plastic grip seal bags. However, this storage method caused the material to become electrically charged, leading to adherence to the bags' surfaces. Despite attempts to mitigate this issue using a deionizer, the effectiveness was limited, resulting in difficulties during material weighing and handling.

These challenges underscore the importance of refining and expanding standard procedures to address practical considerations encountered during testing. By enhancing clarity and specificity in protocol guidelines, such issues can be minimized, ensuring the reliability and reproducibility of test results.

4.2 Comparison between the versions of SFS-EN ISO 20200 standard

The disintegration test adhered to the guidelines outlined in the standard SFS-EN ISO 20200:2015. However, it is worth noting that the updated version of the standard was published in 2023. Upon reviewing both versions, it was found that there were no substantial differences that would impact the execution of the test or the evaluation criteria for its validity.

Comparing the two standards revealed that the version of 2023, is essentially an updated iteration rather than a significant overhaul. Some minor modifications were made to Clause 3 which consists of terms and definitions, where the term “laboratory scale composting” was added.

In Clause 4 “Principle”, the updated version specifies two types of incubation for the composting process. Type 1 describes the incubation at a constant temperature of 58°C for 84 days, while Type 2 describes the incubation process with a decreasing temperature, starting at 58°C for 56 days followed by 45°C until 84 days. The purpose of adding a two-type incubation method was to stimulate a decreasing temperature profile, providing a more comprehensive approach similar to the establish standard (ISO 16929). The core procedures, calculations, and assessment criteria remained consistent with the previous version.

Clause 7.1 “Test material preparation” also received a few updates. Both versions of the standard describe procedures for preparing test materials and initiating a disintegration test but differ in some aspects. The old standard specifies fixed dimensions for test materials based on thickness, with materials less than 5 mm thick being cut to 25 × 25 mm and those greater than 5 mm to 15 × 15 mm and includes a step where dried test materials are immersed in distilled water for up to 30 seconds. In contrast, the updated standard provides a range of dimensions (25 to 50 mm × 25 to 50 mm for materials under 5 mm thick and 15 to 25 mm × 15 to 25 mm for those 5 mm or thicker) and accommodates irregularly shaped materials by maintaining specific area ranges. The updated standard omits the water immersion step, which may indicate that the step is not that crucial and that it could be skipped.

Overall, the transition to the updated standard from 2023 does not have any major adjustments in the conduct or interpretation of the disintegration test. Both versions maintain congruency in their essential aspects, ensuring continuity and reliability in testing procedures.

4.3 Proposing improvements for future version of the standard

Focusing on the odour analysis and visual appearance measurements, the existing standard falls short in clearly stating all possible characteristics that the synthetic waste could have in terms of odour and visual appearance. Currently, the standard lacks specific guidelines on the expected smell or appearance of synthetic waste, offering only a short description of changes throughout the testing process. An avenue for significant enhancement lies in broadening the standard to encompass diverse outcomes concerning odour and visual appearance.

An effective improvement to elevate the standard would involve incorporating a spectrum of possibilities regarding synthetic waste attributes. For instance, delineating specific odours and visual cues, along with their implications for test validity, would enhance clarity and precision. Introducing an "odour wheel" encompassing all potential odours throughout the testing phases could be particularly beneficial.

The idea behind an odour wheel is to categorize smells systematically, aiding users in transitioning from general descriptors to more precise ones. In disintegration testing, these odour wheels can help practitioners in recognizing and addressing odours promptly and pinpointing potential issues with the synthetic waste. (BioCycle, 2014.)

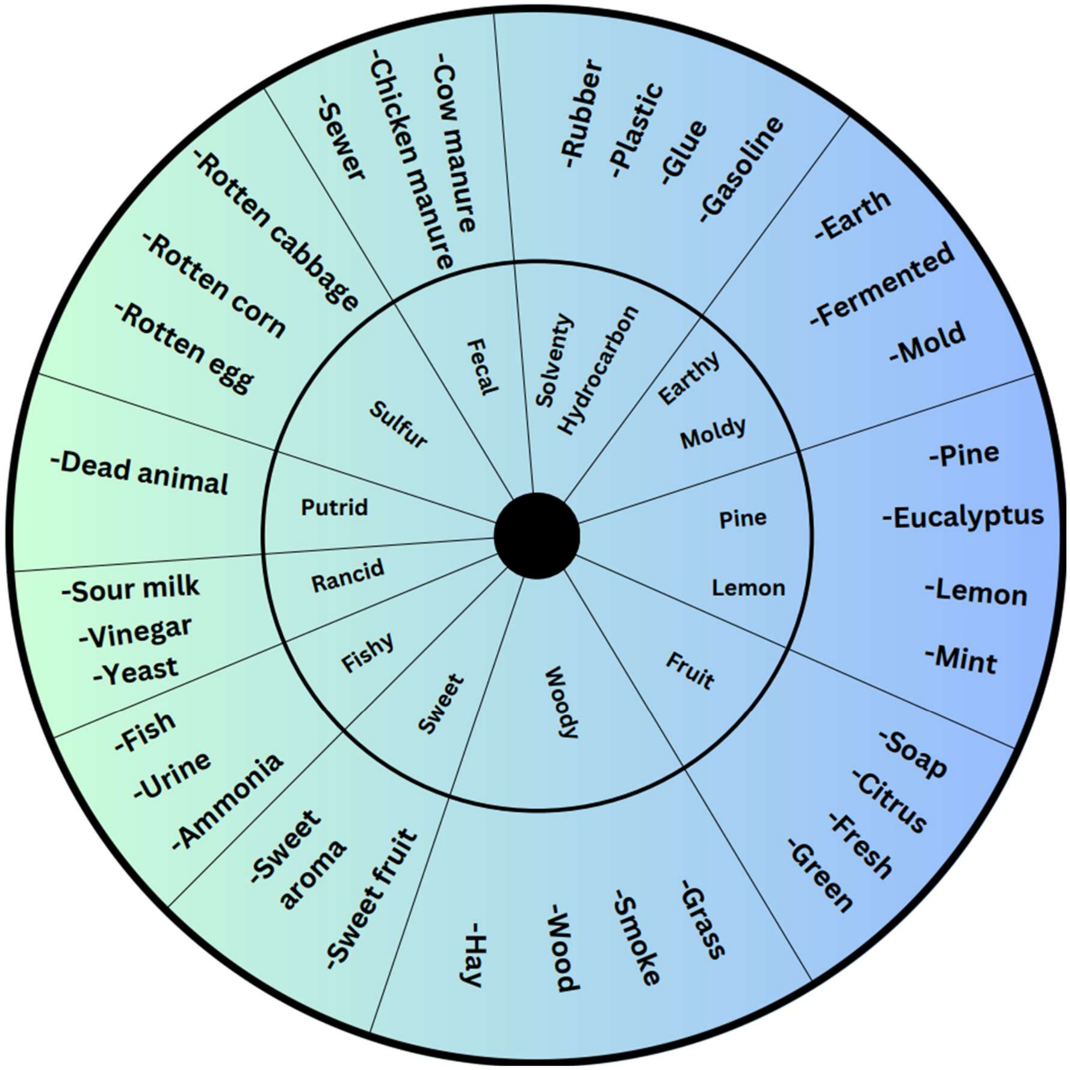

FIGURE 1. Odour wheel (Rosenfeld & Suffet, 2003, modified.)

By integrating these enhancements, the standard would evolve into a more comprehensive and informative framework, empowering the readers with a nuanced understanding of synthetic waste properties and facilitating more accurate assessments.

Another suggestion for enhancing the standard could be providing more explicit guidance on sample cutting procedures. Currently, there is a lack of clarity regarding the tools and methods to be employed for sample cutting, leaving practitioners to rely on their discretion. This ambiguity introduces the potential for errors, however minor, that could impact the accuracy of results and potentially influence test outcomes.

Furthermore, addressing the storage of samples could be essential for ensuring consistency and reliability in testing procedures. The standard currently overlooks recommendations regarding the most suitable containers and storage environments for samples. Incorporating guidelines on appropriate storage containers and conditions would mitigate uncertainties and variability in sample preservation, and by doing so strengthening the integrity of test results.

By incorporating these suggested improvements, the standard would provide practitioners with a more comprehensive framework, reducing the likelihood of errors and enhancing the overall reliability of test outcomes.

5 CONCLUSION

In conclusion, the disintegration test of both hydrophobic and hydrophilic materials has been conducted successfully in accordance with the SFS-EN ISO 20200:2015 standard, along with its normative references and other relevant standards, including SFS-EN ISO 15934, SFS-EN ISO 15935:2021, SFS-EN ISO 16169, and SFS-EN ISO 10390:2005. The SFS-EN ISO 20200:2015 standard provides a solid foundation for conducting such tests, offering clear guidelines and procedures. However, as evidenced by the research findings, there is room for improvement to achieve more detailed results.

While the standard serves as a reliable framework for initial assessments, further enhancements are necessary to address the need for more precise and nuanced outcomes. Specific refinements in methods and materials are required to ensure the accurate execution of the test and the attainment of comprehensive results. There should be more focus on the analysis of odour and visual appearance of synthetic waste. These elements offer valuable perspectives that enriches and strengthens the standard. Looking deeper into the odour and visual appearance not only enhance the understanding but also elevates the efficacy of waste management practices.

In summary, while the existing standard provides a satisfactory starting point for disintegration testing, it is imperative to strive for continual improvement in methodologies and protocols to meet evolving research needs and standards of precision. By implementing these enhancements, researchers can enhance the reliability and utility of disintegration test outcomes in various applications and industries.

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