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Literature-Based Feasibility Analysis of Ginkgo Fruit Odor Removal Strategies

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Abstract. Ginkgo biloba is a widely-planted urban ornamental tree, yet malodorous fallen fruits create seasonal olfactory disturbances for local residents. This paper adopts a literature-based feasibility-analysis approach to explore feasible deodorization strategies targeting ginkgo-fruit odor. According to existing literature, the unpleasant odor mainly originates from butanoic acid and hexanoic acid. This study summarizes their key physicochemical properties including vapor pressure, solubility and low odor-detection thresholds to interpret observed odor-release behaviors. Four technical pathways (washing, adsorption, chemical reaction and biodegradation) are screened, and acid-base neutralization is further prioritized as a promising route. A qualitative 1-5 scoring matrix is established to evaluate four alkaline reagents (NaOH, $NaHCO_3$, $Ca(OH)_2$ and Na_2CO_3) across effectiveness, safety, cost, practicality and environmental-concern dimensions. Scoring outcomes indicate that sodium carbonate delivers relatively balanced overall performance, despite its moderate neutralization capacity. Further mechanism analysis suggests that water washing is constrained by hexanoic acid's low water solubility, while activated-carbon adsorption is limited by reversible desorption under ambient conditions. Other chemical pathways such as esterification, reduction and ketonization face obvious practical barriers for outdoor community deployment. This literature-driven assessment implies sodium carbonate represents a comparatively promising candidate reagent for urban ginkgo-fruit odor mitigation, providing theoretical references for subsequent experimental validation and practical community-level applications.

Keywords: Ginkgo Biloba Fruit Odor, Deodorization Strategies, Acid-base Neutralization, Sodium Carbonate, Literature-based Feasibility Analysis

1. Introduction

Ginkgo biloba is a highly prevalent ornamental tree widely planted in urban residential zones, community parks and roadside green belts across temperate regions [1]. Its strong adaptability and ornamental foliage make it a preferred landscaping choice for city planners, yet its mature fruits bring an overlooked seasonal nuisance to local residents. During autumn, when the ginkgo fruit get ripen, they would fall off the ground where pedestrians would pass by. People would unconsciously step on to the fruit and let the bad smell of the fruit be released into the air. Even mild contact with

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crushed fruit releases a sharp, rancid scent that lingers on footwear and spreads to nearby residential buildings [2]. Many residents avoid opening their windows during the fruiting period, and parents tend to restrict children's outdoor play on ginkgo-lined streets to prevent contact with the odorous pulp. In order to avoid the smell, what people could only do was to bypass the roads with bad smell, which created inconvenience to them. These malodorous fruits appear annually for several weeks each fall, affecting basic daily routines including evening walks, window ventilation and outdoor leisure to a certain extent. Therefore, choosing an appropriate deodorization strategy that would be relatively feasible for evaluating potential deodorization strategies based on chemical properties is vital for this issue.

The objective of this study is to evaluate potential deodorization strategies for ginkgo fruit odor and identify the most feasible candidate based on chemical mechanism, effectiveness, safety, cost, practicality, and environmental considerations. More specifically, this study does not experimentally measure odor reduction but provides a literature-based feasibility assessment to guide future experimental validation. In doing so, the disturbance of ginkgo smell to people's daily life could be largely alleviated, effectively relieving the olfactory troubles brought by ginkgo trees to local residents.

Existing temporary countermeasures such as regular street sweeping only provide limited short-term relief, as new ripe fruit keep falling continuously throughout the fruiting season. Fewer low-cost, easy-to-operate household or community deodorization solutions have been widely adopted to target this recurring issue. Although existing research has mature methods to remove odors, most published chemical odor removal studies focus on industrial waste gas or large-scale food processing facilities, and limited research attempts to apply existing methods to reduce the odor of ginkgo, exploring simple, accessible chemical neutralization or adsorption techniques specifically designed for fallen ginkgo sarcocarp.

2. Methodology

This study employs literature-based feasibility analysis as its core foundational methodology across all experimental and analytical procedures. To guarantee comprehensiveness, accuracy and scientific rigor, relevant domestic and international publications, peer-reviewed journals, specialized monographs and authoritative industrial reports were systematically collected, reviewed and analyzed. By synthesizing the current research progress, well-established theories, existing outcomes and unresolved gaps concerning this topic, this work builds a reliable theoretical framework for subsequent experimental design and result analysis, defines the overall research structure and core objectives, and provides adequate theoretical support for project implementation, scientific validation and result discussion. Butanoic acid and hexanoic acid were selected as the target odor-causing compounds based on previous studies of volatile constituents in ginkgo exocarp. Their physicochemical properties, including vapor pressure, water solubility, boiling point, pKa, and odor threshold, were collected from chemical databases and published literature [3]. These properties were used to infer how the odor molecules may behave under different deodorization pathways.

On the basis of prior fundamental research, odor dispersion is governed by molecular thermal diffusion, generated by the continuous random Brownian motion of gas-phase molecules in ambient conditions. Consequently, the offensive odor emitted from ginkgo fruits arises from the volatilization of odor-active compounds within fruit tissues. Previous phytochemical and aroma-component investigations have identified two short-chain fatty acids, butanoic acid and hexanoic acid, as the primary odor-causing compounds in ginkgo fruit [2]. Quantitative compositional data

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from authoritative food-science literature indicate that butanoic acid and hexanoic acid account for 59.96% and 25.45% of total odor-related fatty-acid components, respectively [4]. After identifying these key odorants and their concentration profiles, this study performed an in-depth analysis of target compounds butanoic acid and hexanoic acid's physicochemical properties, intrinsic chemical reactivity, molecular structural characteristics, and environmental stability. Based on comprehensive literature screening and mechanism analysis, four typical and feasible deodorization technical strategies were selected as the core research candidates, including washing, adsorption, chemical reaction, and biodegradation. Specifically, washing achieves odor removal by dissolving and eluting surface-attached short-chain fatty acids through solvent rinsing; adsorption captures volatile odor molecules via physical interfacial interaction using porous adsorbents; chemical reaction eliminates malodor through stable chemical transformation of butanoic acid and hexanoic acid into low-odorous products; and biodegradation realizes odor abatement via microbial metabolic degradation of odor-causing fatty acid components. Among chemical reactions, acid-base neutralization was further evaluated because butanoic acid and hexanoic acid are carboxylic acids that can theoretically be converted into less volatile carboxylate salts. Four alkaline reagents, NaOH, $NaHCO_3$, $Ca(OH)_2$, and Na_2CO_3, were compared. Beyond the targeted removal and suppression of odor-producing substances, multiple critical practical criteria, including operational safety, actual deodorization efficiency, technical feasibility, economic cost, and environmental concern were considered during the strategy screening and experimental design process. A literature-derived qualitative 1–5 scoring matrix as also constructed to quantitatively and qualitatively evaluate the above four candidate strategies, thereby improving the rationality, practicability and comprehensiveness of the final experimental protocol. No experimental validation was conducted. The evaluation criteria included expected effectiveness, safety, implementation cost, practicality, and environmental concern. A score of 1 represented poor feasibility, 3 represented moderate feasibility, and 5 represented strong feasibility. Because no experiment was conducted, the scoring results should be interpreted as theoretical feasibility rather than direct evidence of deodorization efficiency.

3. Result and discussion

3.1. Physicochemical basis of odor persistence

This study first summarizes key physical-chemical parameters of the two main odor-producing short-chain fatty acids derived from ginkgo fruits, butanoic acid and hexanoic acid. Multiple critical properties including molecular formula, molecular mass, phase characteristics, vapor pressure, pKa, odor threshold and water-solubility are collected and organized [3], as shown in Table 1. These fundamental parameters lay the physical-chemical basis for subsequent screening of feasible deodorization strategies.

Table 1. Physical and chemical properties of butanoic and hexanoic acid

	Butanoic acid	Hexanoic acid
Molecular formula	$C_4H_8O_2$	$C_6H_{12}O_2$
Molecular mass	88.11 g/mol	116.16 g/mol
Feature	Oily, colorless liquid Saturated fatty acid Unpleasant odor	Oily Goat-like odor

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Table 1. (continued)

Vapor pressure	0.43 mmHg at 68 °F	0.2 mmHg
pKa	4.38 at 25 °C	4.8
Odor threshold	0.0013 ppm	0.0025 ppm
Boiling point	163.5 °C	396 °F
Solubility	100 mg/mL	10 mg/mL
Density	0.958 g/cm^3	0.927 g/cm^3
Melting point	-5.7 °C	-3.4 °C

As illustrated in Table 1, obvious property gaps exist between butanoic acid and hexanoic acid. Noticeable differences can be observed in water-solubility, vapor pressure and odor threshold. Although both substances possess low vapor-pressure values, their extremely low odor thresholds enable human noses to detect trace-level volatile molecules, which accounts for the persistent offensive smell of ginkgo fruit. Besides, their distinct solubility performance creates major limitations for simple water-washing removal. Such observed differences further imply that single-physical-based treatments cannot achieve complete odor elimination.

3.2. Comparison of alkaline reagents

Based on the property analysis above, neutralization reaction has been identified as the most promising technical route. Four widely-available alkaline reagents were further evaluated from multiple practical dimensions including neutralization capacity, safety, solubility, environmental risk, cost and operability. Each indicator was scored on a 1-5 scale (1 = poor, 5 = excellent). The comprehensive assessment results are presented in Table 2.

Table 2. Alkaline reagent suitability assessment

Treatment	Mechanism	Effective-ness	safety	Implementation cost	practicality	Environment-al concern	Overall (average)
NaOH	Strong neutralization	5	1	1	1	1	1.8
$NaHCO_3$	Mild neutralization	1	5	5	5	5	4.2
$Ca(OH)_2$	Alkaline neutralization	5	1	5	3	1	3
Na_2CO_3	Moderate alkaline neutralization	3	5	5	5	5	4.6

Note: 1=poor 3=moderate 5=strong

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When assessing four alkaline-neutralization treatments via a 1-to-5 qualitative scoring framework (higher scores represent more favorable performance), sodium hydroxide (NaOH, strong neutralization, overall = 1.8) obtained an effectiveness score of 5 [5]. This full score is justified by the robust strong alkalinity of NaOH, which delivers rapid, stoichiometrically complete neutralization reactions with butanoic acid and hexanoic acid—the dominant short-chain fatty acid odorants liberated from decomposing fallen ginkgo sarcocarp under ambient outdoor conditions. It can potentially eliminate the acidic odor precursors in a short treatment window, achieving likely optimal deodorization effectiveness among all tested reagents. Nevertheless, it received a minimum score of 1 for safety, cost, practicality and environmental concern, with rigorous justifications as follows. For safety (1): NaOH is a highly corrosive strong base with severe tissue irritation and erosion properties; direct or indirect contact with skin and ocular tissues during on-site spraying and residue handling will cause chemical burns and irreversible mucosal damage, posing persistent and non-negligible personal injury risks to community residents and field construction operators. For cost (1): Professional grade protective clothing, chemical-resistant gloves, goggles and specialized spraying equipment are mandatory for operational safety; the procurement, maintenance and replacement of these dedicated facilities generate substantial additional economic input, significantly elevating the real-world large-scale implementation cost compared with conventional mild reagents. For practicality (1): NaOH is classified as a hazardous chemical with strict municipal safety supervision and usage specifications. Its on-site application requires standardized hazard assessment, professional operator certification and closed operational procedures, which greatly complicates community-scale green space treatment and fails to support simple, rapid and widespread field deployment. For environmental concern (1): Post-reaction NaOH residues produce high concentrations of sodium-rich alkaline byproducts that accumulate in surface soil. Long-term residue accumulation drastically elevates soil pH value, disrupts urban soil acid-base balance and microbial community structure, and inhibits the normal growth and metabolism of surrounding landscape vegetation, resulting in sustained negative ecological impacts.

Sodium bicarbonate ($NaHCO_3$, mild neutralization, overall = 4.2) scored a full mark of 5 across safety, cost, practicality and environmental concern, with solid practical and environmental justification [6]. For safety (5): $NaHCO_3$ is a low-irritation, non-corrosive household and food-grade reagent with extremely low acute and chronic health risks. It causes no chemical damage to human skin, respiratory tract or ocular tissues even under direct contact during manual spraying, ensuring full operational safety for community volunteers and field staff. For cost (5): The raw material is mass-produced and commercially accessible at an ultra-low market price, with no additional supporting facilities or protective equipment required, leading to negligible overall treatment cost for large-area urban application. For practicality (5): It features stable chemical properties, simple dilution and deployment procedures, and no rigorous operational constraints. Untrained personnel can complete standardized spraying operations efficiently, fully adapting to flexible and rapid community green space management. For environmental concern (5): Its neutralization residues are mainly sodium salts and carbonate buffer substances, which will not induce drastic soil pH fluctuation. The residues can be naturally degraded and metabolized by soil microorganisms, causing no long-term cumulative damage to urban soil ecosystems and landscape plants. In contrast, it achieved a minimum effectiveness score of 1. The weak alkalinity of $NaHCO_3$ results in low chemical reaction activity and incomplete neutralization capacity. Under complex outdoor field conditions with variable temperature, humidity and wind exposure, it cannot fully react with butanoic acid and hexanoic acid, leaving substantial residual odor-active fatty acid precursors and failing to achieve effective ginkgo fruit odor elimination.

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Calcium hydroxide ($Ca(OH)_2$, alkaline neutralization, overall = 3.0) yielded a high effectiveness rating of 5 [7]. Its medium-to-strong alkaline reactivity and high hydroxyl ion concentration enable efficient and thorough neutralization and saponification reactions with ginkgo-derived malodorous short-chain fatty acids, consuming odor-causing substrates and delivering superior deodorization efficiency equivalent to NaOH in field applications. However, it was assigned the lowest score of 1 in safety and environmental impact. For safety (1): $Ca(OH)_2$ is a corrosive alkaline substance that can produce severe chemical irritation and erosive damage to human skin and mucous membranes. Dust inhalation or solution contact during construction easily triggers respiratory discomfort and skin burns, posing consistent personal safety hazards for field operators, consistent with the risk profile of corrosive NaOH. For environmental impact (1): Repeated field application leads to continuous accumulation of calcium-containing alkaline residues in surface soil, which causes excessive soil alkalinization and soil hardening. This alters urban soil physicochemical properties, destroys soil nutrient balance, and suppresses the growth of shallow-rooted urban landscape plants, resulting in persistent adverse ecological effects. Additionally, $Ca(OH)_2$ received a full cost score of 5 due to its extremely low bulk purchase price and wide industrial supply channels, with no high raw material cost pressure for large-scale application. It obtained an intermediate practicality score of 3, as raw material acquisition is convenient, but mandatory safety protection operations and residue treatment procedures restrict operational flexibility, resulting in mediocre comprehensive application feasibility.

Sodium carbonate (Na_2CO_3, moderate alkaline neutralization, overall = 4.6) achieved a mid-range effectiveness score of 3 [8]. Its moderate alkalinity provides appropriate neutralization activity that can partially react with and degrade target odor-causing fatty acid molecules to reduce ginkgo fruit odor intensity, yet it cannot completely consume all odor precursors under field conditions, thus failing to achieve full odor elimination. Notably, it was awarded full-mark ratings of 5 for safety, cost, practicality and environmental concern with comprehensive empirical justification. For safety (5): Na_2CO_3 features mild chemical properties and low acute toxicity; it only causes mild irritation under extreme high-concentration contact and poses limited health threat to operators and surrounding residents during conventional outdoor low-dose spraying. For cost (5): It is a bulk industrial and commercial chemical with mature market supply and ultra-low unit price, supporting low-cost large-area popularization and application in urban green spaces. For practicality (5): The reagent is easy to store, dissolve and deploy, with simple operational workflows and no professional certification or complex hazard control procedures required, perfectly matching the efficient, grassroots-oriented management mode of urban community greening. For environmental concern (5): When applied at standard optimal dosages, its reaction residues will not trigger drastic soil pH variation or soil salinization. The residues are environmentally benign and can be gradually assimilated by soil ecosystems, with less risk of severe or long-term ecological disruption. This balanced multi-criterion performance profile implies that sodium carbonate serves as a highly promising and practical candidate for urban ginkgo-fruit odor mitigation.

According to the scoring results demonstrated in Table 2, each alkaline candidate shows distinct strengths and limitations in practical application. NaOH delivers outstanding neutralization deodorization performance but suffers from harmful drawbacks in operational safety, economic cost and ecological compatibility, resulting in extremely poor practical application value. By contrast, sodium carbonate (Na_2CO_3) obtains the highest average composite score across all evaluation dimensions. It achieves well-balanced and reliable performance in neutralization efficiency, operational safety, on-site practicality, environmental compatibility and economic affordability. In this way, $NaHCO_3$ and Na_2CO_3 both show high feasibility, but Na_2CO_3 may be preferred when

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stronger neutralization capacity is needed. Therefore, sodium carbonate appears to be a comparatively feasible alkaline reagent for ginkgo-fruit odor mitigation in this literature-based assessment. However, its actual deodorization efficiency and environmental effects require experimental validation under controlled and field conditions.

3.3. Odor treatment techniques selection

Both butanoic acid and hexanoic acid exhibit relatively low vapor pressure, recorded at 0.43 mmHg and 0.2 mmHg respectively, with both values significantly lower than the vapor pressure of water at 17.54 mmHg under ambient conditions. From a purely physical perspective, such low volatility characteristics seem insufficient to account for the strong, unpleasant odor emitted by ginkgo fruits, as low-vapor-pressure substances typically release volatile molecules at a relatively slow rate. Nevertheless, the two fatty acids possess extremely low olfactory detection thresholds, measured at 0.0013 ppm and 0.0025 ppm accordingly, both of which are far below the common threshold standard of 0.01 ppm for odor perception.

In fact, human olfactory systems are extremely sensitive to short-chain fatty acid compounds, which enables trace amounts of these volatile molecules to be effectively perceived even at extremely low atmospheric concentrations. In odor science, the odor detection threshold often plays a more decisive role than vapor pressure in determining whether a substance produces a noticeable smell. A compound with low volatility but an ultra-low odor threshold can still generate a strong and persistent offensive odor, which may help to explain why ginkgo fruits release a pungent smell despite the low vapor pressure of its odor-causing components. This fundamental sensory property serves as the core explanation for their distinct offensive smell, allowing trace concentrations of volatile molecules to be easily detected by human olfactory systems and may contribute to persistent odor pollution.

The limited performance of simple water washing treatment can be reasonably explained based on the differential water solubility of the two odor-causing components. Structural differences in carbon chain length lead to significant differences in the hydrophilicity and solubility of butanoic acid and hexanoic acid. Butanoic acid has a shorter carbon chain, stronger molecular polarity, and higher hydrophilicity, allowing it to dissolve readily in water and be effectively removed through conventional rinsing. In contrast, hexanoic acid contains a longer hydrophobic carbon chain, which greatly reduces its overall water affinity, resulting in only moderate solubility of approximately 10 mg/mL. Such limited solubility may greatly restrict the removal efficiency of water washing. Consequently, a considerable proportion of hexanoic acid, which accounts for 25.45% of total odor-causing fatty acid components, may remain stably retained on the ginkgo fruit surface after washing, continuously releasing malodorous substances and sustaining unpleasant odor emission. Therefore, simple water rinsing may only eliminate butanoic acid but might fail to fully remove hexanoic acid residues.

Similarly, activated carbon adsorption appears to be somewhat impractical for thorough odor elimination [9]. Activated carbon relies on physical adsorption to capture organic molecules through its porous structure, yet its adsorption capacity is limited and non-permanent under natural environmental conditions. Activated carbon may only capture a portion of the odor-causing fatty acid molecules within its effective adsorption range. Environmental fluctuations, including slight temperature increases, atmospheric humidity changes, and continuous air flow, will gradually weaken the intermolecular van der Waals forces responsible for physical adsorption. Once the porous structure of activated carbon reaches saturation, unstable physically adsorbed compounds may undergo desorption and re-release into the external environment. This reversible adsorption

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mechanism suggests that activated carbon may not achieve complete and permanent odor removal, which may render it less suitable for practical long-term ginkgo deodorization treatment.

Typical chemical reactions applicable to organic fatty acids, including esterification, reduction, ketonization, and neutralization, were comprehensively evaluated in this study to screen for optimal deodorization approaches. The first three reaction types exhibit obvious practical limitations and may not be applied effectively in routine public-area deodorization operations. Specifically, the esterification reaction is chemically reversible under natural ambient conditions [10]; the generated ester products may gradually hydrolyze back into original fatty acid reactants with changes in temperature and humidity, which might hinder thorough and stable long-term odor removal. The reduction reaction requires specific chemical reducing agents and precise catalytic conditions [11], which increases operational complexity, safety risks, and overall application cost, making it less suitable for large-scale outdoor treatment. Furthermore, ketonization strictly demands extremely high-temperature environments above 300 °C and specialized metal oxide catalysts [12], which are typical industrial reaction conditions that are difficult to implement for daily public environmental management.

In contrast, the acid-base neutralization reaction demonstrates comprehensive practical advantages and is suggested as the most suitable treatment strategy. This reaction may proceed spontaneously and rapidly under normal room temperature conditions without requiring additional catalysts, high temperature, or high pressure, which may support simple, safe, and accessible field operation. The final reaction products are water and stable inorganic salt substances, both of which are non-toxic, chemically inert, and environmentally friendly, with low potential for secondary pollution or harmful residues to the surrounding ecological environment. Meanwhile, various commercially available alkaline reagents provide sufficient and convenient material support for practical neutralization treatment.

Four commonly used alkaline substances were further systematically compared in terms of alkalinity strength, operational safety, solubility characteristics, treatment efficiency, environmental friendliness, and economic applicability [5-8]. Sodium hydroxide (NaOH) possesses the strongest alkalinity and optimal instantaneous reaction efficiency; however, its strong corrosiveness, irritation, and high operational risk make it unsafe and less favorable for large-scale application in open public environments. Calcium hydroxide ($Ca(OH)_2$) also belongs to strong alkalis yet suffers from extremely low water solubility, which may easily lead to insoluble solid residues and white sediment deposition after treatment, potentially causing visual pollution and surface contamination on roads and sidewalks. Sodium bicarbonate ($NaHCO_3$) exhibits weak alkalinity and limited chemical reactivity, which may result in insufficient reaction efficiency and inadequate deodorization performance for eliminating fatty acid odor components. By comparison, sodium carbonate achieves relatively well-balanced comprehensive performance: it possesses moderate yet effective alkalinity that may support thorough neutralization efficiency, maintains stable and safe application properties without corrosive hazards, produces no insoluble residues, and features low cost and easy accessibility for practical field operation. Therefore, sodium carbonate is suggested as a comparatively appropriate alkaline reagent for efficient, safe, and sustainable ginkgo fruit deodorization treatment.

3.4. Limitations and future work

The scoring criteria applied for evaluating the four types of bases in this study relies primarily on theoretical odor characteristics and preliminary qualitative observation, which inevitably introduces a certain degree of subjectivity and uncertainty to the assessment results. Due to the lack of real

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environmental interference factors and on-site verification data, the comprehensive scoring outcomes may not fully reflect the practical deodorization efficacy under complex natural conditions. Therefore, supplementary validation based on real-world application performance is essential to verify the reliability and practicability of the current evaluation system. To address this research limitation and further optimize the deodorization strategy for ginkgo biloba fruits, future systematic experimental investigations are highly required. Specifically, controlled laboratory experiments should be conducted first to standardize treatment parameters, including solution concentration, processing duration, and reaction temperature, so as to clarify the optimal operating conditions of sodium carbonate deodorization. Meanwhile, field trials under natural environmental scenarios need to be implemented to quantify the actual odor removal efficiency, eliminate the interference of ambient temperature, humidity and microbial activities, and obtain authentic and applicable deodorization data. In addition, subsequent studies should comprehensively assess the potential environmental impacts of sodium carbonate treatment, such as residue pollution, soil and vegetation adaptability, and ecological safety risks, thereby providing comprehensive, scientific and feasible theoretical support for the large-scale practical promotion and industrial application of ginkgo fruit odor reduction technology.

4. Conclusion

This literature-based feasibility analysis evaluated washing, adsorption, chemical reaction, and biodegradation as potential strategies for reducing odor from fallen ginkgo fruit. Based on previous studies and prior literature, the analysis treated butanoic acid and hexanoic acid as the principal odorants and compared treatments using their physicochemical properties. Water washing is likely constrained by the relatively low water solubility of hexanoic acid. Activated-carbon adsorption may also be limited by saturation and desorption under changing outdoor conditions. Among the chemical approaches considered, acid-base neutralization appears to offer the most practical route because it can convert carboxylic acids into less volatile carboxylate salts under mild conditions.

Within the qualitative scoring matrix, sodium carbonate received the highest average score of 4.6 across expected effectiveness, safety, cost, practicality, and environmental concern. This result identifies sodium carbonate as a candidate for experimental testing rather than a confirmed deodorization treatment. Because the scoring was derived from literature and no laboratory or field experiments were conducted, actual odor reduction, optimal treatment conditions, and ecological effects remain uncertain. Controlled laboratory studies, followed by field trials, are therefore required before sodium carbonate can be recommended for community-scale use.

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