Research Article BEU Fen Bilimleri Dergisi 15(1): 300-311 (2026) DOI: 10.17798/bitlisfen.1801494

BİTLİS EREN UNIVERSITY
FEN BİLİMLERİ DERGİSİ
ISSN: 2147-3129 / e-ISSN: 2147-3188

INVESTIGATION OF THE UTILIZATION POTENTIAL OF TOBACCO PLANT WASTE ASH IN CERAMIC BODIES

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Article Info

Received: *October 11, 2025*
Revised: *November 24, 2025*
Accepted: *December 23, 2025*

Keywords

Ceramics,
Glaze,
Tobacco,
Ash addition,
Sustainable material.

ABSTRACT

This study aims to evaluate the potential use of tobacco plant waste ash as an alternative raw material in ceramic bodies. Although various agricultural residues such as rice husk ash, olive waste, and coffee husk have been widely investigated in ceramics, studies specifically focusing on the effects of tobacco ash in ceramic bodies remain extremely limited. In this research, tobacco waste obtained from Adıyaman (Turkey) was characterized using XRF, and ICP-MS analyses. Grog-based and casting-slip-based bodies were formulated with 0–25 wt% ash additions, fired at 1160 °C, and examined in terms of water absorption, linear shrinkage, color changes, and surface morphology. The results indicate that low to moderate ash additions (3–10 wt%) promoted sintering, controlled porosity, and produced more stable microstructures. The lowest water absorption values were obtained in samples ST10 (15.75%) and DT0 (19.8%). However, higher ash additions (20–25 wt%) significantly increased porosity, with water absorption rising to 31.3% in DT25, indicating reduced densification efficiency. Total shrinkage exhibited an irregular trend in grog-based bodies due to the non-plastic nature of chamotte. Overall, the findings demonstrate that tobacco ash can be incorporated into ceramic bodies at optimal levels of 10–15 wt%, within which acceptable water absorption, controlled microstructural behavior, and desirable surface characteristics can be achieved. Thus, tobacco ash represents both an environmentally sustainable raw material alternative and an innovative functional additive capable of modifying ceramic body properties.

1. INTRODUCTION

The ceramic industry is associated with high energy consumption, carbon emissions, and environmental impacts stemming from raw material extraction, water use, waste generation, and atmospheric pollutants. These impacts can be mitigated through integrated strategies emphasizing resource efficiency, recycling, and material substitution [1]. In this context, the partial replacement of natural raw materials with waste-derived alternatives has gained prominence, contributing both to environmental sustainability and economic efficiency. Numerous studies report that industrial and domestic wastes such as fly ash (FA), rice husk ash (RHA), blast furnace slag (BFS), sludge, glass waste, polished tile waste, and eggshells can reduce the use of virgin raw materials, supporting the "waste-to-value ceramics" approach [2].

Recent research has expanded the potential of incorporating diverse waste types into ceramic bodies. For instance, textile waste has been shown to decrease natural resource consumption and contribute to improved waste management and circular economy practices [3]. Biomass-derived ashes have also attracted growing attention: firewood ash has enabled low water absorption at reduced firing temperatures [4], while olive pruning residue ash and waste vegetable oil ash have been successfully utilized as high-percentage additives in ceramic brick production [5]. These findings illustrate that various industrial and agricultural residues can enhance sustainable ceramic manufacturing.

Agricultural waste, in particular, has become a key focus due to its environmental advantages and widespread availability. Studies show that such residues improve mechanical performance, reduce porosity and shrinkage, and lower dependence on natural resources [6, 7]. Applied research further confirms that agricultural ashes such as rice husk ash, bagasse ash, and palm oil industry ash can enhance density, flexural strength, and water absorption performance at appropriate firing temperatures [8, 9]. Similarly, previous studies report that aggregate additions (e.g., basalt, slate, sandstone) reduce body shrinkage while enhancing natural surface texture, whereas perlite [10], owing to its high amorphous silica content increases porosity and modifies sintering behavior; together, these findings provide a meaningful comparative basis for evaluating tobacco plant waste ash as an alternative ceramic body additive [11].

Despite extensive work on agricultural ashes, research specifically addressing tobacco plant waste ash remains limited. Existing studies primarily evaluate tobacco ash as a cement substitute, demonstrating improved compressive strength at certain replacement levels [12, 13]. Although cigarette butts have been explored as additives in roof tiles and ceramic bodies [14, 15], the ceramic use of tobacco plant waste ash itself has not been sufficiently investigated, revealing a clear gap in the literature.

Tobacco holds significant global importance, with a market size of 8.76 million tons in 2024 [16]. Turkey produced 99,000 tons of tobacco in the same year, with the Southeastern Anatolia Region particularly Diyarbakır-Silvan, Bitlis-Muş, and Adıyaman being major producers [17, 18]. The abundance of tobacco residues in Adıyaman provides a locally accessible agricultural waste source, forming the primary motivation for this study.

Accordingly, this research examines the potential use of tobacco plant waste ash as an alternative raw material in ceramic body production. Grog-based and slip-cast bodies with varying ash additions were prepared, fired at 1160 °C, and analyzed in terms of water absorption, shrinkage, color development, and surface morphology.

2. MATERIAL AND METHOD

In this study, a sequential analytical procedure was employed to determine the effects of tobacco plant waste ash on ceramic bodies. In the first stage, locally sourced tobacco residues were collected, combusted, and converted into ash (Figure 1). The obtained raw material was initially characterized morphologically through Scanning Electron Microscopy (SEM) analysis. Subsequently, the chemical oxide composition of the ash was determined by X-Ray Fluorescence (XRF) analysis conducted at the Department of Mining Engineering, İnönü University. Following the XRF analysis, the elemental composition and trace element contents were verified through Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) performed at the BILTEM Laboratory of Adıyaman University. After this characterization process, chamotte-based and slip-casting ceramic bodies containing different proportions of tobacco ash were prepared, shaped, fired at 1160 °C, and subjected to physical testing.

a b c

Figure 1. Stages of the preparation of tobacco plant waste ash.

The experimental part of this study aims to determine the effects of tobacco plant waste ash on ceramic bodies employed in the field of art. Initially, local tobacco waste was collected, combusted, and processed. Subsequently, the chemical and physical properties of the resulting ash were characterized using appropriate analytical techniques. These analyses are critical for understanding the activity of the waste material within ceramic bodies and its compatibility with other structural additives. Tobacco plant waste and ash were subjected to a two-stage analytical procedure at the Adıyaman University Science and Technology Application and Research Center. Mechanical and durability tests of the prepared samples were performed, and the results were comprehensively evaluated by comparing them with the existing literature.

For ceramic body formulations, grog-based bodies were coded as *ST*, whereas casting slip-based bodies were coded as *DT*. The proportions of tobacco ash incorporated into the experimental compositions were systematically varied at 3%, 5%, 10%, 15%, 20%, and 25%. The coding system for ceramic bodies (ST and DT) and the incremental ash ratios (3–25%) were designed in accordance with similar experimental frameworks reported in the literature [19]. This coding and systematic design enabled the organized presentation of experimental applications and facilitated comparative evaluation of the results.

SEM analyses provided significant findings from both a materials science and an aesthetic perspective. In order to investigate the morphological structure of tobacco plant waste ashes in detail, Scanning Electron Microscopy (SEM) analyses were conducted, providing important findings both in terms of materials science and aesthetics. The raw material (Figure 2) exhibited a distinct fibrous, cellular, and porous structure, reflecting the high organic and cellulosic content of the tobacco plant. This fibrous morphology suggested that the ash obtained after pyrolysis (combustion) would similarly exhibit irregular and porous particle characteristics. Beyond scientific characterization, SEM images also revealed aesthetic potential at the micro scale, with observable organic textures, stratifications, and random geometric formations. These natural and spontaneous structures can serve as inspiration for new formal approaches and surface designs in contemporary ceramic art.

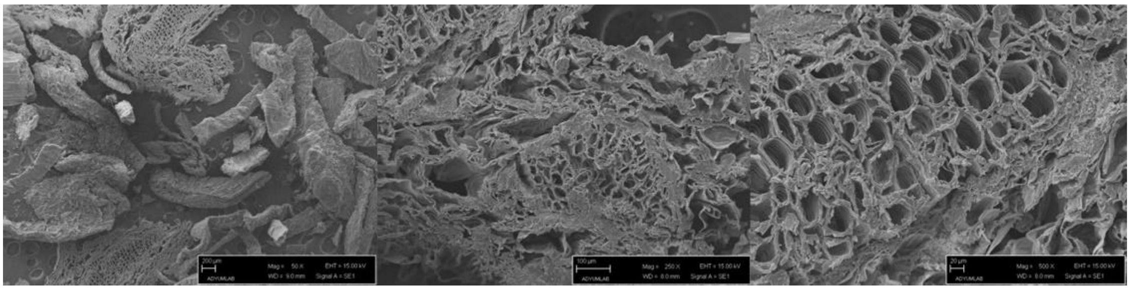

Figure 2. Scanning electron microscopy (SEM) images of raw tobacco plant waste.

In this context, the process of analyzing tobacco ash represents not only the generation of scientific data but also a pathway of artistic exploration, adding a new interpretive dimension to its application in art ceramics. Thus, the analysis provided a critical starting point for understanding the physical properties of the ash to be incorporated into ceramic bodies, while simultaneously laying the foundation for an interdisciplinary design approach.

XRF analyses were conducted on both raw-burned and calcined tobacco ash samples, enabling the determination of their chemical compositions prior to their incorporation into ceramic bodies (Tables 1–2).

Table 1. Chemical oxide composition of raw-burned tobacco ash (XRF)

Compound	MgO	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	Fe_2O_3	CO_2
Conc	4.535	1.843	1.707	2.672	5.274	18.316	30.938	0.669	30.00
Unit	%	%	%	%	%	%	%	%	%

The chemical composition of the raw-burned tobacco ash is characterized primarily by its high CaO (30.938%) and K_2O (18.316%) contents. These oxides are key components that influence melting behavior and phase formation at high temperatures within ceramic bodies. In contrast, the notably low SiO_2 content (1.843%) indicates that the development of a glassy phase will depend largely on other silica sources present in the body. The high CO_2 content (30%) suggests incomplete decomposition of carbonate compounds, implying a potential for volumetric instability, gas release, and resulting porosity during thermal treatment. Therefore, the direct use of raw-burned tobacco ash may lead to structural defects during sintering. Table 1 demonstrates that while raw ash can act as a flux-modifying additive affecting phase development, its high CO_2 content necessitates additional thermal processing.

Table 2. XRF results of calcined tobacco ash.

Compound	Na_2O	MgO	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	Fe_2O_3	CO_2
Conc	0.153	3.538	2.097	1.153	1.035	3.726	14.309	50.026	1.204	0.00
Unit	%	%	%	%	%	%	%	%	%	%

The calcined tobacco ash exhibits a more stable composition following heat treatment. The substantial increase in CaO content to 50.026% indicates a chemical structure capable of significantly influencing high-temperature phase transformations. The K_2O content (14.309%) provides an alkali oxide contribution that promotes melting and glass-phase formation during sintering. The complete removal of CO_2 confirms that the calcined ash will not produce gas-related volumetric defects during firing and will display a more predictable sintering behavior. Although SiO_2 remains relatively low, the combined presence of CaO and K_2O can facilitate the development of high-temperature phases in silica- and alumina-based ceramic bodies. For this reason, calcined ash is more stable and functions as a more effective sintering-modifying additive compared to raw-burned ash.

After determining the oxide composition of the ash by XRF analysis, ICP-MS analysis was performed to conduct a more detailed elemental assessment. The ash determination process involved the combustion of tobacco plant residues to identify their chemical composition. The procedure was carried out using a Perkin Elmer NexION 350X ICP-MS instrument. Samples were prepared in a Berghof microwave digestion system with nitric acid (65% HNO_3), following the specified temperature and pressure parameters (Table 3). After microwave digestion, the resulting solutions were diluted to 10 mL with ultrapure water, and the necessary serial dilutions were performed. During ICP-MS analysis, the instrument's standard performance control procedures were applied to verify the accuracy of gas flow rates, RF power, and other operating parameters. This ensured high-precision elemental measurements, providing the chemical data necessary to evaluate the potential of tobacco ash in ceramic body applications (Table 4).

Table 3. Sample digestion procedure.

Step	Temperature (°C)	Pressure (bar)	Power (%)	Ramp time (min)
1	140	40	80	10
2	160	40	80	5
3	180	40	80	5
4	50 (cooling)	0	0	-

Table 4. ICP-MS instrumental operating procedure

Component/Parameter	Type/Value/Mode
Nebulizer	Mainhard (Concentric)
Spray Chamber	Glass Cyclonic
Triple Cone Interface	Nickel
Plasma Gas Flow	18.0 L/min
Auxiliary Gas Flow	1.2 L/min
Nebulizer Gas Flow	0.77 L/min
Sample Uptake Rate	1 mL/min
RF Power	1500 W
Number of Replicates (per sample)	3
Operating Mode	STD/KED Mode
Collision Mode	Performed using He gas.

The Inductively Coupled Plasma Mass Spectrometry (ICP-MS) analyses conducted to determine the chemical composition of tobacco plant waste ash revealed its potential for ceramic applications (Table 5). According to the results, potassium (K) was identified as the most dominant element with a remarkably high concentration of 170,838.996 ppm. Such a high alkali content can facilitate the sintering behavior of ceramic bodies, thereby positively influencing density and mechanical strength. Furthermore, the presence of alkaline earth elements such as calcium (Ca) (43,175.259 ppm) and magnesium (Mg) (30,930.737 ppm) may enhance thermal stability and mechanical performance. Trace elements including zinc (Zn), copper (Cu), manganese (Mn), and vanadium (Vd) suggest potential contributions to color variation and aesthetic characteristics after firing.

This chemical profile supports the consideration of tobacco ash as a sustainable raw material with binding properties in ceramic bodies. The results highlight that controlling the chemical composition and homogeneity of the material during production is critical for optimizing the manufacturing process and achieving denser, more durable ceramic bodies.

Table 5. ICP-MS analysis results of tobacco ash sample.

Parameter	Analysis Method	Result / Unit	Mass %
P (Phosphor)	ICP-MS	9329,555 ppm	0.9330 %
Ca (Calcium)	ICP-MS	43175,259 ppm	4.3175 %
Mg (Magnesium)	ICP-MS	30930,737 ppm	3.0931 %
Na (Sodium)	ICP-MS	1325,181 ppm	0.1325 %
K (Potassium)	ICP-MS	170838,996 ppm	17.0839 %
Fe (Iron)	ICP-MS	7483,146 ppm	0.7483 %
Al (Aluminum)	ICP-MS	4391,301 ppm	0.4391 %
Mn (Manganese)	ICP-MS	387970,115 ppb	0.038797 %
Zn (Zinc)	ICP-MS	166824,530 ppb	0.016682 %
Cu (Copper)	ICP-MS	79369,138 ppb	0.0079369 %
V (Vanadium)	ICP-MS	14670,751 ppb	0.0014671 %

3. RESULTS and DISCUSSION

The effects of tobacco ash additions on ceramic body properties were evaluated through different formulation series. Experiments conducted on both chamotte-based (ST) and casting slip-based (DT) bodies demonstrated that increasing ash content led to significant changes in the physical and chemical properties of the ceramics.

Table 6 presents the formulation compositions of chamotte-based bodies prepared with varying proportions of tobacco ash. While the ash content was gradually increased, the proportions of other raw materials (e.g., clay, quartz) were adjusted on a 100% total weight basis. This adjustment aimed to assess the role of tobacco ash as a fluxing and melting agent within the ceramic body. Accordingly, low ash additions (e.g., 3–5–10 wt.%) and medium-to-high ash additions (15–20–25 wt.%) were comparatively analyzed to observe the variations in physical and chemical properties with increasing ash content.

Table 6. Formulation compositions of chamotte-based bodies prepared with tobacco ash additions

Recipe No	Recipe Composition (%)	
	Chamotte Clay	Tobacco Ash
ST-0	100	0
ST-3	97	3
ST-5	95	5
ST-10	90	10
ST-15	85	15
ST-20	80	20
ST-25	75	25

Table 7 displays the surface appearances of chamotte-based bodies prepared with varying amounts of tobacco ash after biscuit firing at 1160 °C. Examination of the images indicates that specimens with low ash content exhibited darker surface tones, while increasing ash content resulted in progressively lighter colors. Particularly in high-ash samples, the dominance of lighter shades can be attributed to the influence of alkali and alkaline earth oxides in the ash, which affect color development mechanisms within the ceramic body. These findings reveal that the amount of tobacco ash directly influences not only the physical properties of the body but also its aesthetic appearance after firing.

Table 8 provides the formulation compositions of casting slip-based bodies prepared with different amounts of tobacco ash. In these formulations, the ash content was systematically increased, while the relative proportions of other components were readjusted to a total of 100 wt.%. This allowed for a comparative evaluation of the effects of tobacco ash on fluidity, sintering behavior, and porosity of casting slip bodies relative to chamotte-based bodies. Thus, low-ash formulations (e.g., 3–5 wt.%) and medium-to-high-ash formulations (10–25 wt.%) were compared to identify physical and chemical differences.

Table 7. Surface appearances of chamotte-based bodies with tobacco ash additions after biscuit firing at 1160 °C.

Table 8. Formulation compositions of casting slip-based bodies prepared with tobacco ash additions.

Recipe No	Recipe Composition (%)	
	Casting Slip	Tobacco Ash
DT-0	100	0
DT-3	97	3
DT-5	95	5
DT-10	90	10
DT-15	85	15
DT-20	80	20
DT-25	75	25

Table 9 presents the surface appearances of casting slip-based bodies prepared with varying amounts of tobacco ash after biscuit firing at 1160 °C. The images show that as the ash content increased, the surface colors became progressively lighter. However, higher ash contents also led to increased porosity, surface cracking, and reduced plasticity of the body. This indicates that excessive tobacco ash additions negatively affected the sintering behavior of casting slip bodies, thereby reducing material strength. This situation is consistent with studies reporting that high levels of ash addition increase void formation during firing due to the decomposition of organic and carbonate-based components, thereby weakening the sintering behavior [5], [15]. Therefore, it can be stated that excessive tobacco ash additions adversely affect the sintering efficiency of slip-cast bodies and reduce the final material strength.

Table 9. Surface appearances of casting slip-based bodies with tobacco ash additions after biscuit firing at 1160 °C.

	 DT0	
 DT3	 DT5	 DT10
 DT15	 DT20	 DT25

For the total shrinkage and water absorption tests, mixtures of chamotte-based clays containing specified amounts of tobacco ash were blended with water, dewatered on plaster slabs to achieve homogeneity, and then hand-pressed into plaster molds for shaping. In the slip-casting bodies, clay slurries containing tobacco ash were diluted with water, homogenized, and poured into plaster molds using the solid-casting method to obtain test plates [20]. All specimens were shaped in standard molds measuring 10 × 5 × 100 mm to enable consistent measurement of total shrinkage and water absorption. The samples were dried at room temperature to a constant mass and subsequently fired at 1160 °C. After firing, the color, surface characteristics, and melting behavior of the specimens were evaluated.

Table 10 summarizes the total shrinkage, water absorption, and color values of chamotte-based bodies containing varying amounts of tobacco ash fired at 1160 °C. At low ash additions (3–5 wt%), total shrinkage remained relatively stable, while water absorption values were comparatively low, indicating limited open porosity. The incorporation of 10 wt% tobacco ash resulted in the lowest water absorption value, suggesting improved densification and a more compact microstructure. Similarly, at 15 wt% ash addition, the water absorption value remained low (15.55%), implying that no significant increase in porosity occurred within this composition range. In contrast, a pronounced increase in water absorption was observed at higher ash contents (20–25 wt%), reflecting increased open porosity and a decline in sintering efficiency. The total shrinkage data exhibited a fluctuating rather than monotonic trend with increasing ash content, which can be attributed to the inherently non-shrinking nature of chamotte. As a result, total shrinkage is highly sensitive to minor variations in mixture preparation, water content, forming density, and drying–firing conditions; therefore, the observed fluctuations in the ST series are interpreted as natural process-related variations rather than systematic errors. The increase in porosity at higher ash levels is consistent with previous studies reporting that the decomposition of organic and carbonate-based components during firing increases pore volume and adversely affects sintering behavior [4,5]. Likewise, several studies on agricultural waste-derived ashes have demonstrated that excessive ash additions tend to increase porosity and reduce mechanical strength in ceramic bodies [9,15]. Overall, these results indicate that tobacco ash enhances the sintering and densification behavior of chamotte-based bodies up to an optimum level, whereas higher addition rates lead to increased porosity and potential deterioration of mechanical performance.

Table 10. Firing results (1160 °C) of chamotte-based bodies with tobacco ash additions: total shrinkage, water absorption, and color values

Recipe	Body Type	Total Shrinkage (%)	Water Absorption (%)	L*	a*	b*
ST-0	Chamotte	10	16.91	21.45	20.80	3.82
ST-3	Chamotte	10	17,51	16.18	19.60	6.08
ST-5	Chamotte	10	17,61	11.59	15.30	–2.43
ST-10	Chamotte	11	15,75	15.02	25.67	1.83
ST-15	Chamotte	10	15,55	26.17	22.32	–4.07
ST-20	Chamotte	8	19.74	29.84	17.42	–7.16
ST-25	Chamotte	9	22.26	34.68	15.07	–9.57

The total shrinkage values also exhibit a fluctuating profile rather than a consistent trend, varying according to ash addition levels. Due to the non-plastic and non-shrinking nature of grog, total shrinkage is highly sensitive to subtle experimental variations such as mixture preparation, water content, forming density, and drying/firing conditions. Therefore, the fluctuations observed in the ST series are interpreted as natural variations inherent to the material and process, rather than indications of systematic error.

These findings suggest that tobacco ash improves the sintering and densification behavior of grog-based bodies up to a certain threshold, but higher ash additions increase pore formation and weaken mechanical strength. This result is consistent with the literature reporting that low–moderate ash additions positively influence grog- or clay-based ceramic bodies, whereas higher additions lead to increased porosity and reduced material strength [4], [5].

Table 11. Firing results (1160 °C) of casting slip-based bodies with tobacco ash additions: total shrinkage, water absorption, and color values.

Recipe	Body Type	Total Shrinkage (%)	Water Absorption (%)	L*	a*	b*
DT-0	Casting Slip	6	19.8	35.08	9.21	–12.89
DT-3	Casting Slip	6	21.55	36.11	8.59	–13.43
DT-5	Casting Slip	6	22.52	37.07	8.70	–14.17
DT-10	Casting Slip	6	22.83	36.35	8.39	–17.64
DT-15	Casting Slip	6	26.77	43.40	7.73	–18.27
DT-20	Casting Slip	4	28.35	46.36	7.90	–19.44
DT-25	Casting Slip	3	31.3	45.88	7.67	–18.31

Table 11 and Figure 3 presents the total shrinkage and water absorption values of the chamotte and casting-slip-based bodies prepared with varying amounts of tobacco ash and fired at 1160 °C. The data show that total shrinkage remains stable at around 6% for ash additions of 3, 5, 10, and 15 wt%. In contrast, water absorption values range between 19.8% and 26.8% within this addition range, exhibiting a gradual increase as the ash content rises. At 20 wt% and 25 wt% ash addition, the water absorption values increase markedly, reaching 28.35% and 31.3%, respectively. This indicates that higher ash additions negatively affect the density and mechanical integrity of the casting-slip bodies. This trend is consistent with studies reporting that high levels of ash or organic components in agricultural waste additives lead to increased porosity and reduced sintering efficiency, thereby raising water absorption values [4]. Similarly, other studies have reported that waste materials containing high volatile matter increase porosity, reduce density, and elevate water absorption in ceramic bodies [15].

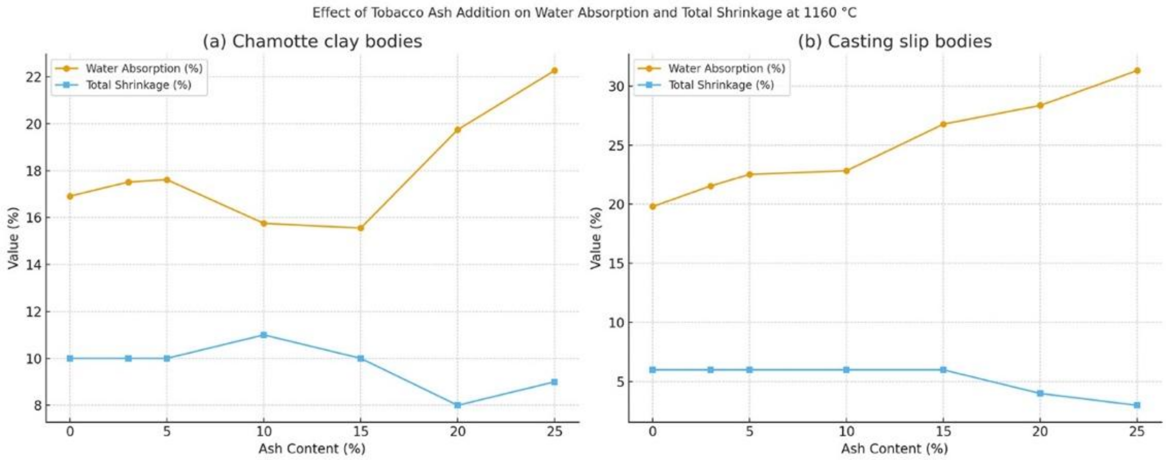

Figure 3. Effect of different ratios of tobacco ash addition on total shrinkage and water absorption values after firing at 1160 °C: (a) chamotte clay bodies, (b) casting slip bodies.

The ST and DT series specimens fired at 1160 °C were immersed in water at room temperature for 24 hours, and their water absorption rates were calculated. The obtained data indicate that the water absorption values of the specimens ranged approximately between 5% and 20%. Color measurements of the bodies were performed using a KONICA MINOLTA CHROME METER CR-400 device. The color parameters (L*, a*, b*) of chamotte and casting slip bodies containing different amounts of tobacco ash after firing at 1160 °C are presented in Figure 4.

In the chamotte bodies (Figure 4-a), the L* values exhibited a consistent increase with increasing ash content, rising from 21.45 in the ST-0 specimen to 34.68 in the ST-25 specimen. This result indicates a clear lightening of the surfaces as the ash ratio increased. The a* values ranged between +15.30 and +25.67, with a tendency toward red at low and medium ash additions, whereas this effect diminished at higher additions. The b* values shifted from positive (e.g., +6.08) to negative (–9.57), revealing a change in surface color from yellowish to bluish tones. These findings demonstrate that the alkali and alkaline earth oxides contained in tobacco ash exert a strong influence on chamotte bodies by lightening the surface color and shifting it toward cooler tones.

In the casting slip bodies (Figure 4-b), a similar trend was observed for the L* parameter. The L* value increased from 35.08 in the DT-0 specimen to 46.36 in the DT-20 specimen, again confirming the surface lightening effect of tobacco ash. The a* values remained relatively stable between 7.67 and 9.21, showing no significant variation along the red–green axis. In contrast, the b* values decreased from –12.89 to –19.44, indicating a progressive shift of the surface color toward bluish tones with increasing ash content.

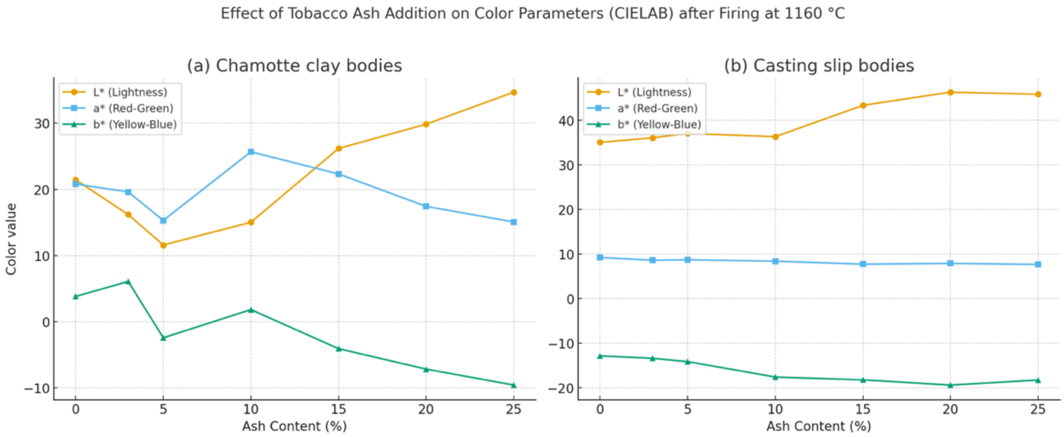

Figure 4. Effect of tobacco ash addition on color parameters (CIELAB system) after firing at 1160 °C: (a) chamotte clay bodies, (b) casting slip bodies.

In order to evaluate the applicability of tobacco plant waste ash in ceramic art, not only the technical analyses but also the forming performance of the ash-incorporated bodies were tested. Within this scope, the grog-based body containing 5% ash (ST5) was shaped using a throwing wheel (Figure 5-a), while the casting slip-based body with 5% ash (DT5) was produced using the slip casting method with plaster molds (Figure 5-b).

In both production methods, it was observed that the form stability was maintained, aesthetically rich textures were achieved on the surface, and no deformation occurred after firing. Specifically, in the grog-based body (ST5), the tobacco ash created a natural matte finish on the surface with deglaze color transitions; in the casting slip (DT5), it was determined that the ash reduced the viscosity, shortened the demolding time (residence time in the mold), and provided a light-toned surface characteristic. These results strongly support that tobacco ash can be functionally utilized as an additive material in both industrial and artistic ceramic production.

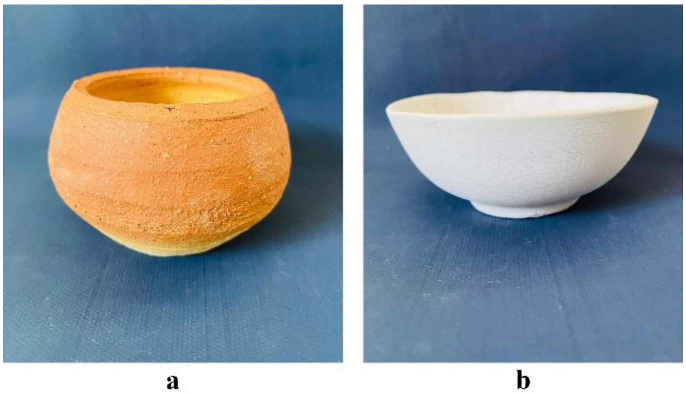

Figure 5. (a) ST5 – Grog-based body containing 5% tobacco ash. Surface appearance of a wheel-thrown sample after firing at 1160 °C. (b) DT5– Casting slip-based body containing 5% tobacco ash. Surface appearance of a slip-cast sample (using a plaster mold) after firing at 1160 °C.

4. CONCLUSION and SUGGESTIONS

This study presents preliminary evaluations on the potential use of tobacco plant waste ash as an alternative raw material in ceramic bodies. The findings indicate that ash addition significantly affects porosity, densification, and color development. In both the ST and DT series fired at 1160 °C, notable variations in water absorption and total shrinkage were observed depending on the ash content.

In grog-based (ST) bodies, the lowest water absorption value was obtained in sample ST10 (15.75%). As the ash content increased to 20 wt% and above, porosity increased and sintering efficiency decreased. In casting slip-based (DT) bodies, water absorption values ranged from 19.8% to 31.3%, with the highest value observed in DT25. This result suggests that DT25 remained structurally porous and that the firing conditions were insufficient to reduce its open porosity.

The literature specifies threshold values for water absorption depending on the intended application of ceramic materials. While stoneware typically requires absorption levels between 0.5% and 3.5%, more porous traditional ceramics may tolerate values up to 10%. Based on this criterion, samples ST25 and DT25 are unsuitable for outdoor applications requiring water and frost resistance due to their high absorption levels. Conversely, samples such as ST10 and DT3 exhibit denser structures with relatively lower absorption values, making them suitable for indoor applications.

Overall, the ST and DT series fired at 1160 °C exhibited porous yet moderately durable ceramic structures. The differences observed between samples highlight the direct influence of body composition and microstructural development during firing on final material performance. To obtain lower water absorption values, increasing the firing temperature or incorporating vitrifying additives into the body composition is recommended.

The findings confirm that tobacco ash can serve as a viable and sustainable raw material alternative in ceramic bodies; however, optimal performance is achieved when ash content is maintained within the 10–15 wt% range. Within this interval, water absorption remains within acceptable limits, and surface properties display more controlled behavior. Higher ash contents result in excessive porosity, undesirable surface defects, and reduced mechanical strength.

Based on these findings, future research on tobacco ash–amended ceramics should incorporate long-term durability assessments such as freeze–thaw cycling, abrasion resistance, and impact strength tests. Systematic investigation of different firing temperatures is also necessary to determine the optimal sintering window. Additionally, exploring the potential use of tobacco ash as a fluxing or matting agent in glaze formulations may broaden its functional applicability. Comparative studies involving other agricultural ashes (such as rice husk ash, olive pit ash, or hazelnut shell ash) will further clarify the position of tobacco ash within sustainable ceramic raw material research. Finally, evaluating the performance of tobacco ash containing bodies in lightweight construction materials, acoustic panels, or low-density decorative ceramics could provide valuable insights for industrial applications.

Acknowledgements

This study was supported by the Scientific Research Projects (BAP) Coordination Unit of Adıyaman University under project number GSFMAP/2024-0001. The authors gratefully acknowledge Adıyaman University for the financial and institutional support provided during the course of this research.

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, analyzed, and prepared by the authors. Artificial intelligence (AI) tools (ChatGPT) were used only for language editing and improving grammatical clarity. All content, including text, data analysis, and figures, was solely generated by the authors.

Contributions of the Authors

Öznur Yıldırım: Research concept, writing – review & editing, experimental design, sample preparation, data acquisition, interpretation of results, and manuscript writing.

Nihal Turan Gül: Methodological support, writing – review & editing, supervision of the experimental process, evaluation of results, and manuscript review.

REFERENCES

[1] D. Del Rio, B. K. Sovacool, A. M. Foley, S. Griffiths, M. Bazilian, J. Kim, and D. Rooney, "Decarbonizing the ceramics industry: A systematic and critical review of policy options, developments and sociotechnical systems" *Renewable and Sustainable Energy Reviews*, vol.157, Art. No. 112081, 2022. doi: 10.1016/j.rser.2022.112081

[2] S. S. Hossain, and P. K. Roy, "Sustainable ceramics derived from solid wastes: a review" *Journal of Asian Ceramic Societies*, vol. 8, no. 4, p.p. 984–1009, 2020. doi: 10.1080/21870764.2020.1815348

[3] V. K. Chauhan, P. Thennarasu, R. Dubey, S. Pandey, and R. Naresh, "Recent efforts and advances towards sustainable ceramics made from textile wastes – A review" *Open Ceramics*, vol.16, Art. no.100500, 2023. doi: 10.1016/j.oceram.2023.100500

[4] F. P. S. Gomes and J. N. F. Holanda, "Recycling of firewood ash waste in ceramic floor tiles with low water absorption" *Materials Research*, vol. 26, Suppl. 1, Art. no. e20220543, 2023. doi: 10.1590/1980-5373-mr-2022-0543

[5] J. M. Terrones-Saeta, J. Suárez-Macías, F. J. Iglesias-Godino, and F. A. Corpas-Iglesias, "Study of the incorporation of biomass bottom ashes in ceramic materials for the manufacture of bricks and evaluation of their leachates," *Materials*, vol. 13, no. 9, Art. no. 2099, 2020, doi: 10.3390/ma13092099.

[6] S. W. Ali, S. Bairagi, and D. Bhattacharyya, "Valorization of agricultural wastes: An approach to impart environmental friendliness" *Handbook of Biomass Valorization for Industrial Applications*, S. Islam (Ed.) Hoboken,N.J., USA: Wiley-Blackwell, 2022, p.p. 369–394.

[7] Y. Bwambale, V. A. Yiga, and M. Lubwama, "Utilization of agricultural residues in ceramic tiles: A review" *Open Ceramics*, vol. 22, Art. no. 100783, 2025.

[8] İ. Özkan, and E. Dokumacı, "Düşük yoğunluklu seramik üretiminde atık kil ve pirinç kabuğu külünün geri dönüştürülmesi" *El-Cezerî Fen ve Mühendislik Dergisi*, vol. 8, no. 1, p.p. 309–314, 2021.

[9] W. Loetchantharangkun, and U. Wangrakdiskul, "Combination of rice husk ash, bagasse ash, and calcium carbonate for developing unglazed fired clay tile", *AIMS Materials Science*, vol.8, no. 3, p.p. 434–452, 2021.

[10] F. S. Başar, and B. Acartürk. "Perlit katkılı seramik bünye özelliklerinin araştırılması" *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi*, vol.22, p.p.1149–1156, 2022.

[11] B. Acartürk, and Ş. Kaya. "Agrega katkılı seramik bünye özelliklerinin araştırılması" *Sakarya Üniversitesi Fen Bilimleri Dergisi*, vol.17, no.2, p.p. 65–69, 2013.

[12] P. Moreno, R. Fragozo, S. Vesga, M. Gonzalez, L. Hernandez, I. D. Gamboa and J. Delgado, "Tobacco waste ash: A promising supplementary cementitious material" *International Journal of Energy and Environmental Engineering*, vol.6, no. 1, p.p. 1–13, 2018.

[13] A. Khan, M. A. Sikandar, M. T. Bashir, S. A. A. Shah, B. Zamin, and K. Rehman, "Assessment for utilization of tobacco stem ash as a potential supplementary cementitious material in cement-based composites" *Journal of Building Engineering*, vol.53, Art. No. 104531, 2022.

[14] L. A. R. Maciel, R. L. Loiola, and J. N. F. Holanda, "Feasibility of using cigarette butts waste in eco-friendly ceramic roofing tile," *SN Applied Sciences*, vol. 2, no. 12, 2020, doi: 10.1007/s42452-020-03672-4.

[15] Q. Yuan, A. Mohajerani, A. Kristoforus, H. Kurmus, U. Chowdhury, D. Robert, B. Pramanik, and P. Tran, "Recycling cigarette butts in ceramic tiles," *Buildings*, vol. 12, no. 1, Art. no. 17, 2022, doi: 10.3390/buildings12010017.

[16] IMARC Group*, Tobacco Market Size, Share, Trends and Forecast by Type and Region, 2025–2033*, 2024. [Online]. Available: https://www.imarcgroup.com

[17] Aegean Tobacco Exporters' Association [ETİB], *2024–2025 Working Report*, İzmir, Türkiye, 2025.

[18] İpekyolu Development Agency, *Adıyaman İli Tütün Raporu*, Gaziantep, Türkiye, 2013.

[19] A. C. Kayalıoğlu, "Investigation of the effects of opacifying and matting metal oxides on the body properties of chamotte clay," M.S. thesis, Institute of Fine Arts, Anadolu University, Eskişehir, Türkiye, 2021.

[20] A. Arcasoy, and H. Başkırkan. *Seramik Teknolojisi*, Ankara, Türkiye: Literatür Yayıncılık, 2020.