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A Comparative Study Between an Alternative Whiteboard Marker Ink Made of Pulverized Chicken Bones and an Industrial Whiteboard Marker Ink

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Abstract

This study investigates the potential of repurposing chicken bones as a sustainable alternative for whiteboard marker ink production. Pulverized chicken bones were compared to traditional industrial ink in terms of absorption, surface tension, and viscosity. Laboratory tests revealed no significant difference in surface tension between the two inks. However, viscosity results differed between observation and laboratory tests, potentially due to the chicken bone ink's absorbency affecting the drip test. The study found significant differences in absorbency between the inks, suggesting the chicken bone ink may require multiple applications. Cost analysis indicates that chicken bone ink is cheaper due to readily available ingredients. The research explores the potential of chicken bone components like proteins (acting as binders) and calcium carbonate (acting as a filler) in ink production. This research contributes to waste reduction and offers a potentially eco-friendly and cost-effective whiteboard marker ink alternative.

Keywords
Pulverized Chicken Bones, Chicken bone ink, Industrial Whiteboard Marker Ink, Whiteboard marker, Absorbance, Viscosity, and Surface Tension.

1. Introduction
Creative solutions are required in response to the growing global concern of waste reduction. Bux and Amicarelli (2022) brought attention to the difficulties in minimizing waste, especially given the lack of a standardized process for separating biowaste, which makes it difficult to value chicken bones, skin, and food waste. This study explores the possibility of using chicken bones for sustainable purposes that promote economic development, environmental health, and waste reduction. While manufacturers prioritize high-quality whiteboard marker ink that delivers exceptional writing performance, durability, and overall efficacy, consumer demands for eco-friendly alternatives are gaining traction (Boz et al. 2020). This study addresses this growing concern by evaluating an alternative whiteboard

marker ink derived from pulverized chicken bones. We compare the ink qualities of both options, focusing on absorption, surface tension, and viscosity on non-absorbent surfaces.

This research has the potential to offer a more practical and sustainable approach to ink production. The findings can benefit various stakeholders:

- Students: Reduced educational costs and potentially minimized exposure to harmful chemicals present in conventional inks.
- Professors: A valuable tool for introducing concepts of sustainability, circular economy, and material innovation in classrooms, fostering critical thinking about materials used.
- Environment: Potential replacement of chemical ingredients with eco-friendly alternatives, promoting environmental safety during production and waste disposal.
- Future Researchers: New insights for expanding the scope of the study and further development using advanced technology.

1.1 Objectives

The study aims to evaluate the efficacy of whiteboard marker ink derived from pulverized chicken bones compared to commercially available industrial counterparts. It seeks to determine whether the chicken bone-derived ink exhibits notable differences in critical characteristics like absorbance, surface tension, and viscosity compared to conventional whiteboard marker inks. Additionally, the research aims to offer insights into the specific contributions of pulverized chicken bone components to the formulation of marker ink. The specific objectives of the study include:

1. To identify if there is a significant difference between the surface tension of pulverized chicken bone marker ink and industrial whiteboard marker ink.
2. To identify if there is a significant difference between the absorbency of the pulverized chicken bone marker ink and the industrial whiteboard marker ink.
3. To identify if there is a significant difference between the viscosity of pulverized chicken bone marker ink and industrial whiteboard marker ink.

To determine how the components of pulverized chicken bones contribute to the production of whiteboard marker ink.

2. Literature Review

The literature review encompasses various studies highlighting the effects of whiteboard marker ink on users and the environment. Studies by Suaidi et al. (2022), Muchemi (2018), and Zhang et al. (2020) emphasize the harmful consequences of exposure to Volatile Organic Compounds (VOCs) present in whiteboard marker ink, such as xylene and formaldehyde, on both health and the environment. VOCs, commonly found in industrial settings, have been associated with adverse health effects ranging from respiratory issues to reproductive harm. Moreover, VOC emissions contribute to environmental pollution, underscoring the importance of exploring eco-friendly alternatives to conventional ink production methods (Suaidi et al. 2022; Muchemi, 2018; Zhang et al. 2020).

Furthermore, the review discusses the occupational hazards faced by workers in the printing industry, particularly regarding exposure to solvents like xylene. Studies by Hormozi et al. (2019) and Geraldino et al. (2021) reveal the correlation between occupational xylene exposure and adverse health effects, emphasizing the need for stringent workplace safety measures. Understanding exposure thresholds and health implications, as outlined by regulatory standards such as OSHA and NIOSH, is crucial for safeguarding worker well-being (Hormozi et al. 2019; Geraldino et al. 2021).

Additionally, the review highlights industry trends toward sustainability and explores strategies for mitigating environmental impact. Research by Rinkesh (2022), Andretta et al. (2021), and Jiang and Qu (2020) underscores the importance of addressing VOC emissions in various sectors, including printing and manufacturing, through innovative approaches and technological advancements. Initiatives such as utilizing biomass waste for ink production and implementing sustainable practices in the manufacturing industry offer promising solutions for reducing environmental footprint (Rinkesh 2022; Andretta et al. 2021; Jiang and Qu, 2020).

Furthermore, valorization studies on chicken bone waste by Pramualkijja et al. (2021) and Hussain et al. (2021) shed light on the potential for utilizing byproducts from the poultry industry in sustainable applications, such as collagen extraction and biodiesel production. These studies underscore the importance of exploring alternative uses for waste materials to minimize environmental impact and promote circular economy principles (Pramualkijja et al. 2021; Hussain et al. 2021).

Overall, the literature review underscores the urgent need for eco-friendly alternatives to conventional whiteboard marker ink production methods, considering the detrimental effects of VOC exposure on human health and the environment. It highlights the importance of adopting sustainable practices in various industries and exploring innovative approaches to waste valorization to mitigate environmental impact and promote a greener future (Suaidi et al.2022; Muchemi 2019; Zhang et al.2020; Hormozi et al. 2019; Geraldino et al. 2021; Rinkesh, 2022; Andretta et al. 2021; Jiang and Qu, 2020; Pramualkijja et al.2021; Hussain et al. 2021).

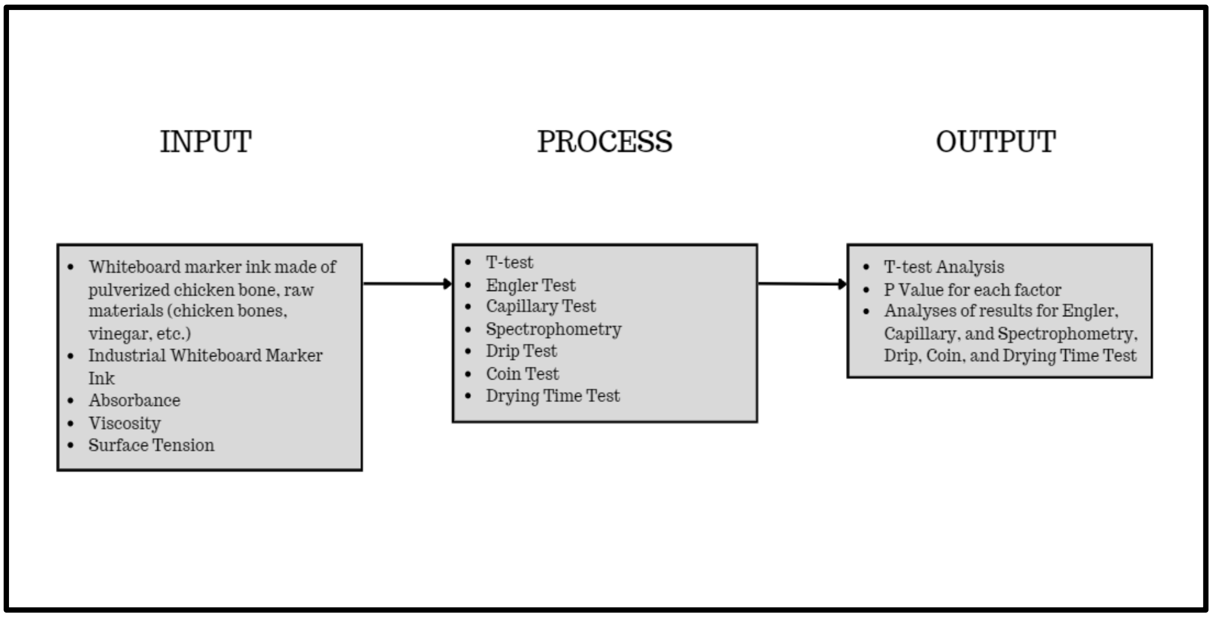

Figure 1. Conceptual Framework

3. Methods

The research explores using pulverized chicken bone as a sustainable alternative for whiteboard marker ink. Various tests and evaluations discovered that this unique substance could effectively produce ink suitable for writing and drawing, presenting a potential eco-friendly solution for ink manufacturing. The conceptual framework outlines the necessary research stages, including input, process, and output. Input involves identifying the components of the product, mainly focusing on the independent variable, while the process entails conducting tests to assess ink quality. The output phase presents the results of hypothesis testing and establishes a relationship between the independent variable (chicken bones) and the dependent variable (ink).

Overall, the research aims to demonstrate the feasibility of using pulverized chicken bone as whiteboard marker ink, highlighting its potential for waste material recycling and reducing environmental impact. By systematically evaluating the components and conducting tests, the study provides insights into the viability and effectiveness of this innovative approach. The conceptual framework guides the research process, ensuring clarity in methodology and facilitating the interpretation of results to determine whether the hypothesis regarding the relationship between chicken bones and ink holds.

4. Data Collection

In collecting data, the researchers will utilize self-observation and laboratory tests. The self-observation tests encompass spectrophotometry and drying time assessments to check the ink absorbance, drip, and Engler tests to evaluate ink viscosity, and coin and capillary tests to analyze ink surface tension. Spectrophotometry measures light absorbance, aiding in understanding ink color intensity and formulation, while drying time tests provide insights into ink drying rates. Drip tests observe ink flow patterns, while Engler tests standardize viscosity measurement. Coin tests assess ink droplet behavior when interacting with a coin, and capillary tests evaluate ink movement through small spaces, reflecting surface tension properties. These tests collectively yield comprehensive data on ink characteristics crucial for optimizing formulations for specific applications.

5. Results and Discussion

The comparative analysis reveals that Ink Trial 1 demonstrates higher absorbency than Industrial Ink, as evidenced by superior results in the Spectrophotometry Test and quicker mean drying time. This heightened absorbency prompts considerations regarding its potential advantages or disadvantages in practical applications. Similarly, Ink Trial 2 exhibits greater absorbency compared to Industrial Ink, which is indicated by superior spectrophotometry results and faster drying time. This leads to inquiries into its efficacy in real-world scenarios. Regarding viscosity, Industrial Ink demonstrates more consistent viscosity, ensuring reliable performance, whereas Ink Trial 2 shows inconsistencies compared to Industrial Ink, despite both displaying inferior performance to the industrial ink in self-observation tests. In terms of surface tension, comparisons between Ink Trial 1 and Industrial Whiteboard Marker Ink, as well as Ink Trial 2 and Industrial Whiteboard Marker Ink, underscore the need for further research to elucidate their effects on ink performance in tasks such as writing or printing on various surfaces.

5.1 Numerical Results

Utilizing IBM SPSS Statistics and Excel, the researchers were able to extensively analyze the correlation between the industrial ink and ink trials 1 and 2, showing the mean, variance, t-stat, p-value, and other relative information. A T-test was utilized during this research.

Data Analysis for Absorbency

t-Test: Two-Sample Assuming Unequal Variances

	Ink Trial 1	*Industrial Ink*
Mean	11.45	27.72666667
Variance	0.9597	13.24843333
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-7.479241989	
P(T<=t) one-tail	0.008705543	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.017411086	
t Critical two-tail	4.30265273	

t-Test: Two-Sample Assuming Unequal Variances

	Ink Trial 2	*Industrial Ink*
Mean	16.36666667	27.72666667
Variance	0.145833333	13.24843333
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-5.376250404	
P(T<=t) one-tail	0.016449692	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.032899384	
t Critical two-tail	4.30265273	

Figure 2. Sample results from the conducted T-test are shown above for comparison with industrial ink and ink trials 1 and 2 in terms of absorbency.

The outputs showcase the degree of association between the two inks based on the resulting p-values. The figure shows that there is a significant difference in absorbency between both ink trials 1 & 2 and the industrial ink.

Data Analysis for Viscosity

t-Test: Two-Sample Assuming Unequal Variances

	Ink Trial 1	*Industrial Ink*
Mean	23.95	11.26666667
Variance	4.8837	3.866433333
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	7.426542972	
P(T<=t) one-tail	0.000877448	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	0.001754896	
t Critical two-tail	2.776445105	

t-Test: Two-Sample Assuming Unequal Variances

	Ink Trial 2	*Industrial Ink*
Mean	16.26666667	11.26666667
Variance	0.731033333	3.866433333
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	4.038976601	
P(T<=t) one-tail	0.013652856	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.027305713	
t Critical two-tail	3.182446305	

Figure 3. Sample results from the conducted T-test are shown above for the comparison of the industrial ink and ink trials 1 and 2 in terms of viscosity.

The outputs showcase the degree of association between the two inks based on the resulting p-values. The figure shows that there is a significant difference in viscosity between both ink trials 1 & 2 and the industrial ink.

Data Analysis for Surface Tension

t-Test: Two-Sample Assuming Unequal Variances

	Ink Trial 1	*Industrial Whiteboard Marker Ink*
Mean	70.37666667	47.51333333
Variance	362.3717333	19.80823333
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	2.025658433	
P(T<=t) one-tail	0.09002805	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.1800561	
t Critical two-tail	4.30265273	

t-Test: Two-Sample Assuming Unequal Variances

	Ink Trial 2	*Industrial Whiteboard Marker Ink*
Mean	74.41333333	47.51333333
Variance	63.10263333	19.80823333
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	5.116902949	
P(T<=t) one-tail	0.007222879	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.014445758	
t Critical two-tail	3.182446305	

Figure 4. Sample results from the conducted T-test are shown above for the comparison of the industrial ink and ink trials 1 and 2 in terms of surface tension.

The outputs showcase the degree of association between the two inks based on the resulting p-values. The figure shows that there is a significant difference in surface tension between both ink trials 1 & 2 and the industrial ink.

5.2 Graphical Results

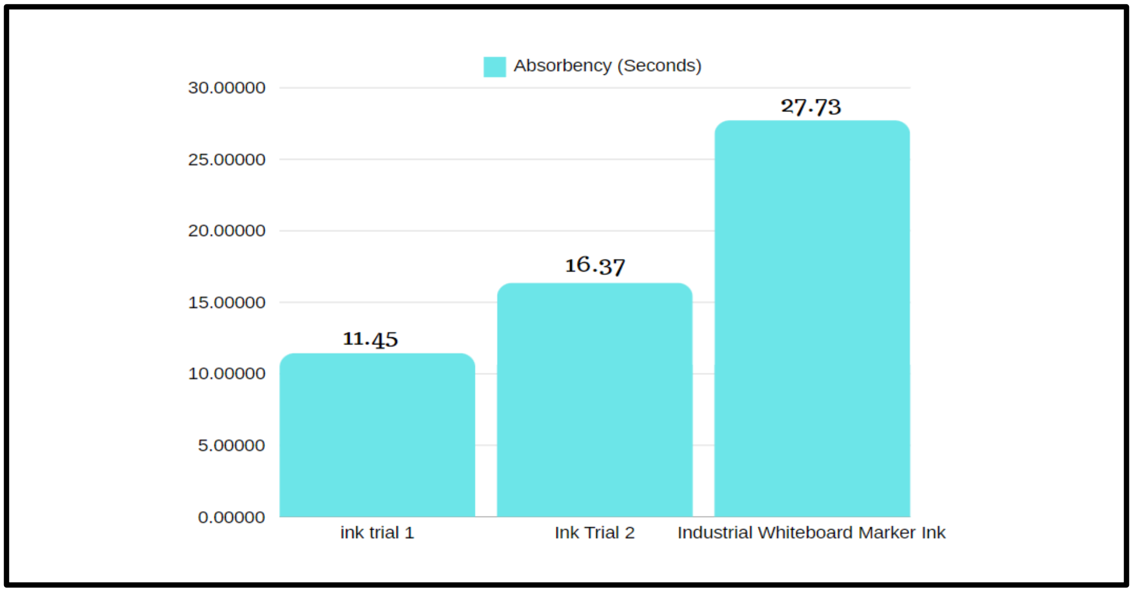

Figure 5. The graph displayed shows the mean outcomes of the 3 inks, Trials 1 and 2, and Industrial Ink from the absorbency test. The ink's absorbency was assessed through an Observation Test (Drying Time).

In the Drying Time test, the mean time for each of the three inks is indicated above, ink trial 1 has a mean time of 11.45 seconds, 16.37 seconds for ink trial 2, and 27.73 seconds for the industrial ink, respectively, dry on a whiteboard surface. These results show that industrial ink is the most effective in terms of absorbency since it does not dry out too quickly, while ink trial 1 was the least absorbent ink from the absorbency test.

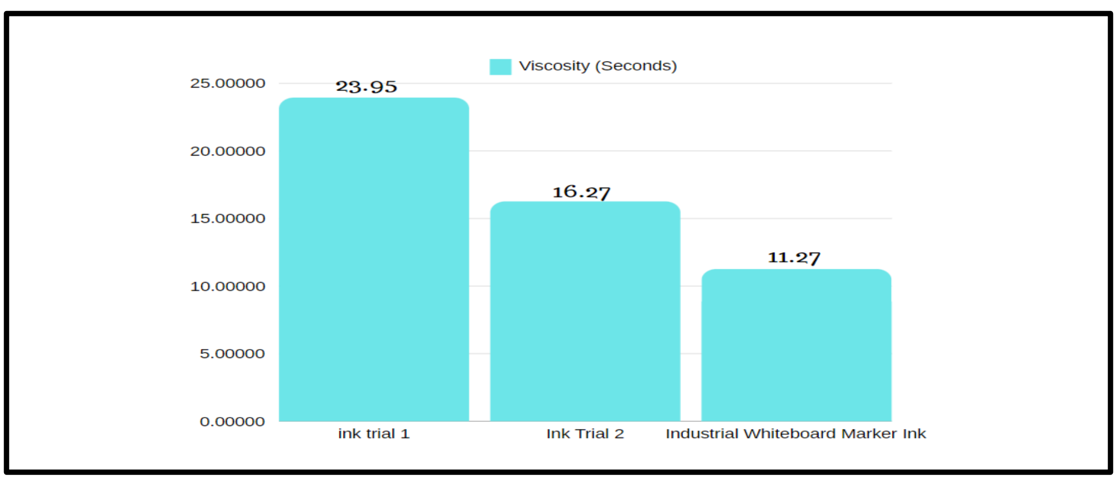

Figure 6. The graph displayed shows the outcomes of the 3 inks, Trials 1 and 2, and Industrial Ink from the viscosity test.

An Observation Test (Drip Test) assessed the ink's viscosity. In the Drip test, the mean time for each of the three inks is indicated above, the ink trial 1 took 23.95 seconds, ink trial 2 took 16.27 seconds, and 31.85 seconds for the industrial ink, respectively, to assess the fluidity of the ink. These results show that industrial ink is the most effective in terms of viscosity, while ink trial 1 was the least effective ink from the viscosity test.

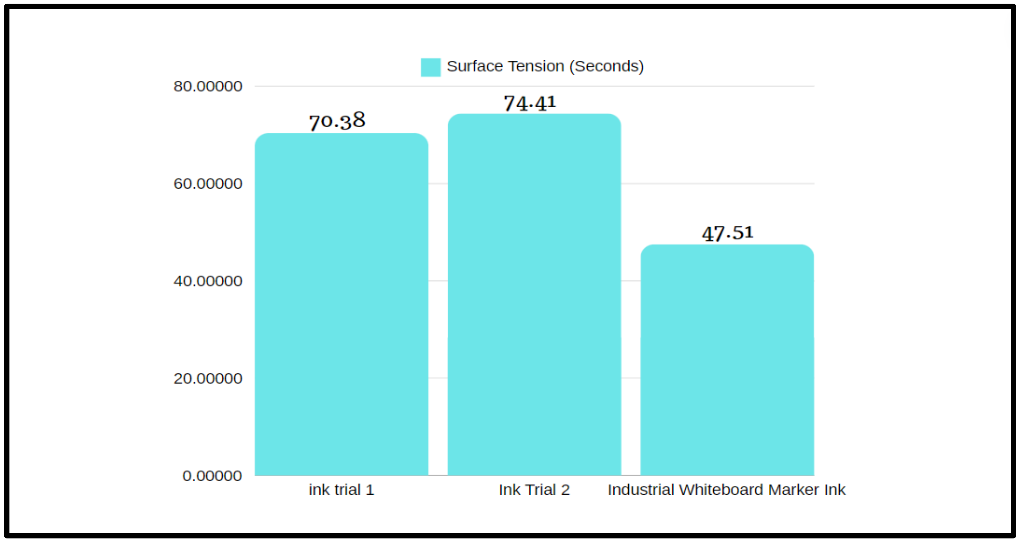

Figure 7. The graph displayed shows the mean outcomes of the 3 inks, Trials 1 and 2, and Industrial Ink from the surface tension test.

An Observation Test (Coin Test) assessed the ink's surface tension. In the Coin test, the mean time for each of the three inks is indicated above, the ink trial 1 has a mean time of 70.38 seconds, 74.41 seconds for ink trial 2, and 47.51 seconds for the industrial ink, respectively, to spread on a whiteboard surface. These results show that industrial ink is the most effective in terms of surface tension since it spreads evenly, while ink trial 2 was the least effective ink from the surface tension test.

5.3 Proposed Improvements

Several areas warrant further investigation regarding chicken bone-based ink. Its long-term durability requires examination, particularly its resistance to fading, erasing, and overall longevity for practical use in various settings. Additionally, a comprehensive environmental impact assessment of the production process is necessary, comparing it to traditional inks to highlight benefits and drawbacks. Chemical composition analysis should identify any potentially harmful substances while emphasizing environmental friendliness. User preferences and market viability, including cost-benefit analysis, need exploration, and alternative chicken bone applications. Comparative studies with other sustainable inks are essential, as is research into utilizing dehydrated chicken bones and identifying components to lower ink absorbance without compromising performance.

5.4 Validation

A Kruskal-Wallis test was performed to validate the T-tests previously performed. the Kruskal-Wallis test does not assume normal distribution or equal variance across groups, making it suitable for situations where these assumptions are violated (Schmidt 2022).

	Absobency			
	Ink Trial 1	**Ink Trial 2**	**Industrial Whiteboard Marker Ink**	
	12.48	16.45	31.85	
	10.53	16.7	26.37	
	11.34	15.95	24.96	
	3	5	9	
	1	6	8	
	2	4	7	
	6	15	24	
	3	3	3	
	12	75	192	279
H0	The mean Absorbency from the Ink Trial 1 , Ink Trial 2, and Industrial Whiteboard Marker Ink are equal.			
H1	The mean Absobency from the Ink Trial 1, Ink Trial 2, and Industrial Whiteboard Marker Ink are not equal.			
Alpha=	0.05			
K=	7.2			
Critical Value	5.99146455			
P-value	0.02732372			
Conclusion	Reject H0			

Figure 8. In this case, after conducting the Kruskal-Wallis test to validate the results of the absorbency of the inks, it is revealed that the null hypothesis (H0), which states that the medians of the groups are all equal, is rejected.

There is evidence to suggest that the medians are different between at least two of the groups.

	Viscosity				
	Ink Trial 1	Ink Trial 2	Industrial Whiteboard Marker Ink		
	25.74	17.12	9.19		
	24.63	16.27	11.51		
	21.48	15.41	13.1		
	9	6	1		
	8	5	2		
	7	4	3		
	24	15	6		
	3	3	3		
	192	75	12	279	
H0	The mean Viscosity from the Ink Trial 1 , Ink Trial 2, and Industrial Whiteboard Marker Ink are equal.				
H1	The mean Viscosity from the Ink Trial 1, Ink Trial 2, and Industrial Whiteboard Marker Ink are not equal.				
Alpha=	0.05				
K=	7.2				
Critical Value	5.99146455				
P-value	0.02732372				
Conclusion	Reject H0				

Figure 9. In this case, after conducting the Kruskal-Wallis test to validate the results of the viscosity of the inks.

It is revealed that the null hypothesis (H0), which states that the medians of the groups are not equal, is rejected There is evidence to suggest that the medians are different between at least two of the groups.

	Surface Tension			
	Ink Trial 1	**Ink Trial 2**	**Industrial Whiteboard Marker Ink**	
	85.59	80.65	46.51	
	49.03	65.47	52.38	
	76.51	77.12	43.65	
	9	8	2	
	3	5	4	
	6	7	1	
	18	20	7	
	3	3	3	
	108	133.3333333	16.33333333	257.6667
H0	The mean Surface Tension from the Ink Trial 1 , Ink Trial 2, and Industrial Whiteboard Marker Ink are equal.			
H1	The mean Surface Tension from the Ink Trial 1, Ink Trial 2, and Industrial Whiteboard Marker Ink are not equal.			
Alpha=	0.05			
K=	4.35555556			
Critical Value	5.99146455			
P-value	0.11329301			
Conclusion	Accept H0			

Figure 10 . In this case, after conducting the Kruskal-Wallis test to validate the results, it failed to reject the null hypothesis (H0) at a significance level of 0.05.

This means there is insufficient evidence to conclude that the mean surface tension differs between the three ink samples. therefore, the data suggests the mean surface tension of all three inks might be similar.

6. Conclusion

The researchers conducted a study to explore the feasibility of using pulverized chicken bones as an alternative to industrial whiteboard marker ink. Laboratory tests were performed to analyze absorbency, viscosity, and surface tension, with results indicating significant differences between the chicken bone ink and industrial ink in absorbency and viscosity. However, surface tension was found to be comparable between the two. Additionally, the cost-effectiveness of the chicken bone ink was highlighted due to its cheaper ingredients. The study also delved into the components of chicken bones, noting the presence of proteins, calcium carbonate, and carbon, which contribute to ink production by acting as binding agents, fillers, and pigments, respectively. This research suggests that while pulverized chicken bone ink may not match industrial ink in all aspects, it presents a potentially cost-effective alternative for specific applications.

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Bibliography

Lander I. Cabuay is a dedicated and results-oriented fourth-year industrial engineering student at the University of Santo Tomas. His passion for optimizing processes extends beyond the classroom, as evidenced by his internship at My Story Inc. There, Lander not only authored engaging marketing content but also made a standard operating procedure (SOP) to streamline content creation. This initiative demonstrates his commitment to efficiency and continuous improvement. Lander is a learner at heart, constantly seeking new skills, and prioritizes delivering high-quality work. As a team player, he values collaboration and understands his colleagues' strengths. Lander's adaptability and openness to new tools and processes make him a valuable asset in any environment focused on operational excellence.

Nikko Carlo C. Caneda, a fourth-year industrial engineering student with a genuine interest in the production field, particularly within manufacturing, has delved into comprehensive study materials and practical experiences to deepen his understanding. His internship at Universal Robina Corporation, a primary food manufacturing company, provided invaluable insights into the intricacies of manufacturing processes, quality control mechanisms, and supply chain management within the food industry. Through this experience, he sharpened his skills in optimizing production workflows, implementing lean methodologies, and enhancing operational efficiency, concentrating his commitment to pursuing a career dedicated to innovation and excellence in manufacturing engineering.

Rcrizthian C. Lao is a dedicated and driven student with a keen interest in operations research and operations management. Their enthusiasm for these subjects extends beyond the confines of the classroom, evident in his internship at “Pacific Paint (Boysen) Philippines” reflects their strong work ethic and pursuit of excellence, allowing them to refine their operational skills and gain valuable insights into logistics and factory management. With a combination of academic perseverance, leadership skills, and a compassionate drive to support others, Rcrizthian is well-equipped for success in the field of operations management.

Jerard Angelo O. Pilipiña, a fourth-year industrial engineering student with a passion for systems engineering processes, my internship at FCU Solutions, Inc. has provided hands-on experience in system procedures. Throughout my academic journey, I've explored various resources to deepen my understanding of the field. My learning journey includes online courses, workshops, and seminars on systems engineering principles and practices. Additionally, I actively engage in online forums and communities focused on industrial engineering and systems optimization. These experiences have not only broadened my knowledge but have also fueled my ambition to contribute to the improvement of industrial systems and processes.

Jesselyn B. Alcain earned a Bachelor of Science Degree in Industrial Engineering from the University of the Philippines Diliman-Quezon City, complementing her academic achievements with a Master's Degree in Management Engineering from the University of Santo Tomas (UST). Presently, she is pursuing a Doctorate Degree majoring in Commerce at UST. With a rich background and extensive experience in industrial engineering, she has contributed significantly to the field, notably through her tenure at a multinational semiconductor company, where she managed various manufacturing process functions. Currently, she leads process improvement initiatives at a non-life insurance company and holds the position of Internal Quality Audit Lead, playing a crucial role in upholding ISO 9001:2015 standards. Additionally, she serves as a part-time lecturer at the University of Santo Tomas' Faculty of Engineering.