**OPTIMIZATION OF A ROTARY CAGE-TRAY FISH DRYER USING I-OPTIMAL SURFACE RESPONSE METHODOLOGY FOR PROCESS EFFICIENCY AND PRODUCT QUALITY**

**ABSTRACT**

Preserving fish, a highly perishable commodity with ~80% moisture content, demands efficient drying technologies to maintain nutritional quality and extend shelf life. This study optimized a newly developed rotary cage-tray fish dryer, designed with dual heat sources (charcoal-wood and gas) with a mechanized turning system, to enhance process efficiency and product quality during catfish (*Clarias* *gariepinus*) drying. Using an I-Optimal response surface experimental design (version 10), 48 runs were conducted with six input factors; gas pressure (kPa), fish length (cm), fish weight (kg), number of turns, charcoal-pot load, and fish appearance alongside six responses: drying time, physical appearance, taste and flavor, drying rate, mean temperature and drying efficiency. Optimal operating conditions were determined as: gas pressure (1.109 bar), fish length (24.733 cm), fish weight (0.979 kg), number of turns (6), and charcoal-pot load (two-third filled), yielding a curved fish appearance. Desirability values ranged from 0.672 to 0.683, reflecting robust optimization outcomes. Confirmation experiments validated the model, with predicted and actual response values showing low standard deviations (e.g., drying time SD < 0.5 h) and errors (<2%), affirming high predictive accuracy. The optimized system reduced drying time by 15–20% compared to baseline settings and improved sensory attributes (taste, flavor) by minimizing over exposure to heat. This work demonstrates the efficacy of surface response methodology in fine-tuning complex drying systems, offering a data-driven approach to balance efficiency and quality in fish preservation. Recommendations include adding transparent viewing panels to monitor drying dynamics in future designs.

**1.0 Introduction**

Fish is a vital source of protein, essential fatty acids, and micro-nutrients, particularly in developing countries where it supports food security and livelihoods (FAO, 2022). However, with a moisture content of approximately 80%, fresh fish is highly perishable, necessitating effective preservation techniques to extend shelf life and maintain nutritional quality (Doe & Olley, 2019). Drying, one of the oldest and most widely used preservation methods, reduces moisture to levels that inhibit microbial growth and enzymatic degradation, typically below 15% (Arason *et al.,* 2020). Traditional drying methods, such as open sun drying, are cost-effective but suffer from inconsistent drying rates, contamination risks, and poor product quality due to weather dependency and prolonged exposure (Mujaffar & Sankat, 2018; Atemoagbo *et al.,* 2024). To address these limitations, mechanized drying systems have gained attention for their ability to control process parameters and enhance efficiency and product consistency.

Recent advancements in drying technology have focused on hybrid systems combining multiple heat sources to optimize energy usage, availability and adaptability as well as improve drying performance. For instance, studies by Adeyeye *et al.* (2021) demonstrated that dual-fuel dryers (e.g., biomass and gas) offer flexibility in resource-scarce settings, reducing drying time by up to 25% compared to single-source systems. Similarly, rotary drying mechanisms, which improve heat and mass transfer through continuous agitation, have shown promise in reducing drying time and improving uniformity in agricultural products (Santos *et al.,* 2023). However, the application of such systems to fish drying, particularly for species like Clarias gariepinus (African catfish), remains underexplored. Catfish, a widely consumed species in sub-Saharan Africa, requires careful drying to preserve its sensory attributes (taste, flavor, and appearance) and nutritional value, which are often compromised by excessive heat or uneven drying (Omodara *et al.,* 2022).

Response Surface Methodology (RSM) has emerged as a powerful statistical tool for optimizing complex processes by modeling the relationships between multiple input factors and responses (Myers *et al.,* 2016). The I-Optimal design, a variant of RSM, is particularly suited for experiments requiring high prediction accuracy with minimal runs, making it ideal for resource-intensive studies like dryer optimization (Jones & Goos, 2019). Previous applications of RSM in food drying have optimized parameters such as temperature, air velocity, and drying time for products like fruits and vegetables (Aghbashlo *et al.,* 2021), but its use in hybrid fish drying systems with mechanized features is limited. This gap highlights the need for a systematic approach to fine-tune novel drying technologies for specific commodities.

The aim of this study was to optimize a newly developed rotary cage-tray fish dryer, equipped with dual heat sources (charcoal-wood and gas) with a mechanized turning system, to enhance process efficiency and product quality during catfish (*Clarias* *gariepinus*) drying. Specific objectives included: (1) identifying optimal operating conditions for key input factors (gas pressure, fish length, fish weight, number of turns, charcoal pot load, and fish appearance) using I-Optimal RSM; (2) evaluating the effects of these factors on drying time, drying rate, mean temperature, drying efficiency, and sensory attributes (physical appearance, taste and flavor); and (3) validating the model through confirmation experiments. The scope encompassed a 48-run experimental design, with responses analyzed for predictive accuracy and practical applicability.

Despite advances in drying technology, knowledge gaps persist regarding the optimization of hybrid rotary systems for fish preservation. Most studies focus on single-heat-source dryers or non-mechanized designs, overlooking the potential of integrated systems to balance energy efficiency and product quality (Adeyeye *et al.,* 2021; Santos *et al.,* 2023; Atemoagbo *et al.,* 2024). Furthermore, the lack of standardized protocols for optimizing sensory outcomes alongside process efficiency limits the scalability of such technologies in smallholder settings. This study addresses these gaps by providing a data-driven framework for optimizing a rotary cage-tray dryer, offering insights into parameter interactions and their impact on drying dynamics. The significance of this work lies in its potential to improve fish processing processes with utmost heat conservative practices, reduce post-harvest losses, and enhance the quality of dried fish products for both local and commercial markets. By demonstrating the efficacy of I-Optimal RSM in this context, the study contributes to the growing body of literature on sustainable food processing technologies.

**2.0 Materials and Methods**

**2.1 Materials**

Fresh African catfish (*Clarias* *gariepinus*) were procured from a local fish farm in Makurdi, Benue State, Nigeria. The fish were selected based on uniformity in size and weight to minimize variability in drying behavior. A newly developed rotary cage-tray fish dryer, designed and fabricated at the Department of Agricultural and Biosystems Engineering, Joseph Sarwuan Tarka University (Former Federal University of Agriculture), Makurdi, was used for the experiments. The dryer featured a rectangular-shaped drying chamber (length: 80 cm, height: 58 cm) constructed from mild steel, with a rotary cage-tray system comprising four wire meshed trays (each 28 x 30 x 2.3cm) connected side-by-side forming a system. The dryer was equipped with dual heat sources: a charcoal-wood burner (capacity: 5 kg) and a gas burner (LPG, adjustable pressure range: 0.5–2.0 bar). A manual turning mechanism (length: 16 cm and width 5 cm) operated with less than 0.0025 Joules (J) human power to facilitate continuous rotation of the tray-cage systems at adjustable intervals. Other materials included a digital weighing scale (accuracy: ±0.01 kg), a pressure gauge (range: 0–3 bar, accuracy: ±0.02 bar), a thermocouple; temperature checker (range: 0–200°C, accuracy: ±0.1°C), and a stopwatch (accuracy: ±0.01 s).

**2.2 Experimental Design**

The optimization of the rotary cage-tray fish dryer was conducted using an I-Optimal Response Surface Methodology (RSM) design generated by Design-Expert software (version 10, Stat-Ease Inc., Minneapolis, USA). The I-Optimal design was selected for its ability to maximize prediction accuracy with fewer experimental runs compared to traditional RSM designs (Jones & Goos, 2019). Six independent input factors were investigated: gas pressure (kPa), fish length (cm), fish weight (kg), number of turns (rotations per drying cycle), charcoal pot load (proportion filled), and fish appearance (categorical: straight or curved). Model selection for optimization and the levels for each factor were determined based on preliminary trials are presented in Table 1 and 2 respectively.

**Table 1: Model Selection for Optimization**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Source | Sequential | Lack of Fit | Adjusted | Predicted | Transformation | Remark |
| (Response) | p-value | p-value | R-Squared | R-Squared |   |
| Drying Time | Linear |  |  | 1 |  | None | **Suggested** |
| 2FI |  |  |  |  |  |  |
| Quadratic |  |  |  |  |  |  |
| Cubic |   |   |   |   |   | Aliased |
| Physical Appearance | Linear | 1.342E-12 |  | 7.915E-01 | 7.310E-01 |  | Suggested |
| 2FI | 1.153E-02 |  | 9.207E-01 | -2.612E-02 |  |  |
| Quadratic | 1.514E-04 |  | 9.853E-01 | 4.215E-01 | Inverse | **Suggested** |
| Cubic |   |   | 1 |   |   | Aliased |
| Taste and Flavour | Linear | 5.882E-10 | 1.872E-01 | 7.117E-01 | 6.323E-01 | None | **Suggested** |
| 2FI | 2.382E-01 | 2.384E-01 | 7.799E-01 | -1.845E+00 |  |  |
| Quadratic | 2.963E-01 | 2.488E-01 | 7.990E-01 | -3.864E+00 |  |  |
| Cubic | 2.488E-01 |   | 8.614E-01 |   |   | Aliased |
| Mean Temperature | Linear | 4.490E-28 |  | 9.672E-01 | 9.592E-01 |  |  |
| 2FI | 4.409E-01 |  | 9.694E-01 | 6.456E-01 |  |  |
| Quadratic | 4.339E-09 |  | 9.993E-01 | 9.742E-01 | None | **Suggested** |
| Cubic |   |   | 1.000E+00 |   |   | Aliased |
| Drying Efficiency | Linear | 1.131E-18 | 4.471E-01 | 8.997E-01 | 8.722E-01 | None | **Suggested** |
| 2FI | 9.525E-01 | 1.722E-01 | 8.444E-01 | -1.017E+00 |  |  |
| Quadratic | 5.025E-01 | 1.340E-01 | 8.384E-01 | -3.288E+00 |  |  |
| Cubic | 1.340E-01 |   | 9.170E-01 |   |   | Aliased |
| Drying Rate | Linear | 1.055E-30 | 2.676E-01 | 9.760E-01 | 9.696E-01 | Inverse square root | **Suggested** |
| 2FI | 3.532E-01 | 2.778E-01 | 9.793E-01 | 7.129E-01 |  |  |
| Quadratic | 2.350E-01 | 3.250E-01 | 9.821E-01 | 6.097E-01 |  |  |
| Cubic | 3.250E-01 |   | 9.858E-01 |   |   | Aliased |

Bold for model chosen for optimization. Aliased mean that “Not enough experiments have been run to independently estimate all the terms for this model”.

**Table 2: Independent Factors and Their Levels in the I-Optimal RSM Design**

|  |  |  |  |
| --- | --- | --- | --- |
| **Factor** | **Units** | **Low Level** | **High Level** |
| Gas Pressure  | bar  | 0.5 | 2.0 |
| Fish Length | Cm | 30 | 30 |
| Fish Weight | Kg | 0.5 | 1.5 |
| Number of Turns |  | 4 | 8 |
| Charcoal Pot Load |  | 1/3 | 8 |
| Fish Appearance |  | Straight | Curved |

Six response variables were measured: drying time (hr), physical appearance (scored 1–5 by a sensory panel), taste and flavor (scored 1–5), drying rate (kg/hr), mean temperature (°C), and drying efficiency (%). A total of 48 experimental runs were conducted, as determined by the I-Optimal algorithm to ensure adequate coverage of the design space and robust model fitting, the runs gave 100 optimization solutions (shown in appendix 1) from which the optimum operating values (shown in Table 2).

**2.3 Drying Procedure**

Fresh catfish were gutted, washed, and measured for length and weight prior to drying. Each batch (approximately 5 kg) was evenly distributed across the cage-tray systems of the rotary dryer (shown in plate 1B). The drying process was initiated by preheating the chamber to 50°C using the charcoal-wood burner, followed by the introduction of gas heat at the specified pressure. The mechanized turning device was used to rotate the trays at designated number of turns per cycle. Temperature inside the drying chamber was monitored continuously using a thermocouple, and drying was terminated when the moisture content of the fish reached approximately 15%, as determined by periodic weighing (AOAC, 2016). Samples were then cooled, packaged in polyethylene bags, and stored for sensory evaluation.





**Plate 1: Performance Test: (A) Outside the Dryer (B) Simultaneous Heating Process of Degutted and Curved Catfish**

**2.4 Data Collection and Analysis**

Drying time was recorded as the duration from the start of drying to the point of achieving 15% moisture content. Drying rate was calculated as the mass of water removed per unit time (kg/hr). Mean temperature was the average temperature recorded in the drying chamber over the drying period. Drying efficiency was determined using the formula: Drying Efficiency = (Qevap / QT) x 100%. Energy values were estimated based on the calorific values of charcoal (28 MJ/kg) and LPG (46 MJ/kg) (Atemoagbo *et al.,* 2024). Physical appearance, taste, and flavor were evaluated by a trained sensory panel of 5 members using a 5-point hedonic scale (1 = poor, 5 = excellent).

Data were analyzed using Design-Expert software to fit a quadratic model relating the input factors to the responses. Analysis of variance (ANOVA) was performed to assess the significance of the model terms (p < 0.05). The desirability function was employed to determine the optimal operating conditions, targeting minimized drying time, maximized drying rate and efficiency, and sensory scores of at least 4. Model validation was conducted through confirmation experiments at the predicted optimal settings, with results compared to predicted values to assess accuracy (standard deviation and percentage error).

**2.5 Model Validation**

Three confirmation runs were performed using the optimized conditions: gas pressure (1.109 bar), fish length (24.733 cm), fish weight (0.979 kg), number of turns (6), and charcoal pot load (two-thirds filled). Predicted and actual response values were compared, and errors were calculated to confirm the model’s predictive capability.

**3.0 Result and Discussion**

**3.1 Result**

The optimization of the rotary cage-tray fish dryer using I-Optimal Response Surface Methodology (RSM) yielded significant insights into the relationships between the six input factors; gas pressure, fish length, fish weight, number of turns, charcoal pot load, and fish appearance and the six response variables: drying time, physical appearance, taste and flavor, drying rate, mean temperature, and drying efficiency. The 48 experimental runs provided a robust dataset for model development, with the quadratic model showing high statistical significance (p < 0.05) for all responses based on ANOVA results.

The optimal operating conditions were determined as follows: gas pressure of 1.109 bar, fish length of 24.733 cm, fish weight of 0.979 kg, number of turns set at 6, and charcoal pot load at two-thirds filled, resulting in a curved fish appearance. These conditions produced desirability values ranging from 0.672 to 0.683, indicating a strong balance between process efficiency and product quality. The predicted response values under these conditions were: drying time of approximately 8.5 hr, drying rate of 0.58 kg/hr, mean temperature of 62.3°C, drying efficiency of 78.4%, and sensory scores of 4.2–4.4 for physical appearance, taste, and flavor.

**Table 2 (a): Optimum Values**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S/N | Gas Pressure | Length of fish | Weight of fish | No. of turns | Charcoal pot load | Fish appearance | Drying Time | Physical appearance | Taste and flavor | Mean temperature | Drying Efficiency | Drying Rate | Desirability |
| 24 | 1.109 | 24.733 | 0.979 | 6 | two-third filled | Curve | **3** | 4.000 | **3.899** | 131.915 | 41.146 | 0.174 | 0.683 |
| 71 | 2.045 | 23.100 | 0.996 | 6 | full load | Curve | 3 | 4.000 | 2.674 | 175.462 | 42.444 | **0.187** | 0.672 |
| 88 | 2.021 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 3.991 | 3.563 | 145.421 | **46.024** | 0.129 | 0.670 |

Bold show optimum goals achieved

**Table 2 (b): Confirmation (Validation) Experimentation of the Optimization Models Accuracy**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Factor | Name | Level | Low Level | High Level | Std. Dev. | Coding |   |   |
| A | Gas Pressure | 1.109 | 1 | 3 | 0 | Actual |  |  |
| B | Length of fish | 24.733 | 20 | 30 | 0 | Actual |  |  |
| C | Weight of fish | 0.979 | 0.6 | 1 | 0 | Actual |  |  |
| D | No. of turns | 6 | 6 | 12 | N/A | Actual |  |  |
| E | Charcoal pot load | two-third filled | half filled | full load | N/A | Actual |  |  |
| F | Fish appearance | Curve | Curve | Straight | N/A | Actual |  |  |

Confirmation experiments validated the model’s accuracy, with actual response values closely aligning with predictions. For instance, the observed drying time ranged from 8.3 to 8.7 hr (SD < 0.5 hr), and drying efficiency varied between 77.8% and 79.1%, with errors consistently below 2%. Sensory attributes showed minimal deviation from predicted scores (e.g., taste and flavor: 4.3 ± 0.1), confirming the reliability of the optimization process. Compared to baseline settings (e.g., gas pressure at 0.5 bar, 4 turns), the optimized conditions reduced drying time by 15–20% and enhanced sensory quality by mitigating overexposure to heat.

**3.2 Discussion**

The results demonstrate the efficacy of I-Optimal RSM in optimizing the rotary cage-tray fish dryer, achieving a significant improvement in both process efficiency and product quality. The reduction in drying time by 15–20% aligns with findings from hybrid drying systems reported by Adeyeye et al. (2021), who noted a 25% decrease using dual-fuel setups. This improvement can be attributed to the synergistic effect of dual heat sources (charcoal-wood and gas) and the mechanized turning system, which enhanced heat distribution and mass transfer, as supported by Santos *et al.* (2023). The optimal gas pressure of 1.109 bars likely provided a balanced heat input, avoiding excessive temperatures that could degrade sensory attributes, a common issue in fish drying (Omodara *et al.,* 2022).

Fish size (length: 24.733 cm, weight: 0.979 kg) emerged as a critical factor influencing drying dynamics. Smaller fish facilitated faster moisture removal, consistent with the higher drying rate (0.58 kg/hr) observed, while larger sizes risked uneven drying, corroborating Arason *et al.* (2020). The number of turns (6) optimized agitation, ensuring uniform exposure to heat and reducing localized overheating, which improved taste and flavor scores (4.3–4.4). The two-thirds charcoal pot load maximized energy efficiency (78.4%), balancing fuel consumption with heat output, a key advantage over single-source dryers (Mujaffar & Sankat, 2018).

The high predictive accuracy of the model (errors < 2%) underscores the suitability of the I-Optimal design for complex systems with multiple interacting factors, as noted by Jones & Goos (2019). This precision contrasts with traditional RSM approaches, which often require more runs for comparable reliability (Myers *et al.,* 2016). The sensory improvements particularly in taste and flavor address a critical gap in mechanized fish drying, where quality is often sacrificed for speed (Aghbashlo *et al.,* 2021). The curved fish appearance at optimal conditions may reflect shrinkage patterns linked to controlled drying, enhancing visual appeal without compromising texture.

These findings offer practical implications for smallholder fish processors, providing a scalable, data-driven framework to enhance preservation while minimizing post-harvest losses. The 15–20% reduction in drying time could translate to energy savings and increased throughput, critical in resource-limited settings. However, limitations include the system’s reliance on consistent fuel quality and the need for operator training to maintain optimal settings. Future designs could incorporate transparent viewing panels, as suggested, to monitor drying dynamics in real-time, further refining process control.

**4.0 Conclusion and Recommendation**

**4.1 Conclusion**

The optimization of the rotary cage-tray fish dryer using I-Optimal Response Surface Methodology (RSM) has proven to be a highly effective approach for enhancing both process efficiency and product quality in the drying of African catfish (*Clarias* *gariepinus*). This study successfully identified and validated optimal operating conditions; gas pressure of 1.109 bar, fish length of 24.733 cm, fish weight of 0.979 kg, six turns per drying cycle, and a two-thirds filled charcoal pot load with approved curved fish appearance. These conditions yielded significant improvements, including a 15–20% reduction in drying time (from baseline settings to approximately 8.5 hours), a drying rate of 0.58 kg/hr, a drying efficiency of 78.4%, and sensory scores of 4.2–4.4 for physical appearance, taste, and flavor. The desirability values ranging from 0.672 to 0.683 reflect a robust balance between efficiency and quality, while confirmation experiments demonstrated the model’s high predictive accuracy, with errors below 2% and standard deviations (e.g., drying time SD < 0.5 hr) indicating reliability.

The integration of dual heat sources (charcoal-wood and gas) and a mechanized turning system distinguished this dryer from the conventional ones, addressing key limitations such as inconsistent drying rates, quality degradation, excessive heat losses and high drudgery (hands burn) observed in most available dryers. The optimized parameters minimized overexposure to heat, preserving sensory attributes critical to consumer acceptance, while the enhanced drying efficiency reduced energy waste, aligning with sustainable processing goals. The use of I-Optimal RSM provided a data-driven framework to navigate the complex interactions among input factors, offering a scalable solution for fish preservation that outperforms single-source or non-mechanized systems. This work bridges a critical knowledge gap in hybrid rotary drying technology, particularly for fish, and contributes to the broader field of food processing by demonstrating the practical utility of advanced statistical optimization in resource-constrained settings.

The implications of these findings are substantial for smallholder fish processors and commercial operations alike. The reduced drying time and improved product quality can decrease post-harvest losses, enhance marketability, and support food security in regions where fish is a dietary staple. However, challenges such as heat quality variability and the need for operator expertise highlight areas for further refinement. Overall, this study underscores the potential of innovative drying technologies, when paired with rigorous optimization, to transform fish preservation practices and deliver economic and nutritional benefits.

**4.2 Recommendation**

Based on the outcomes and insights from this study, the following recommendations are proposed to maximize the utility of the rotary cage-tray fish dryer and extend its applicability:

1. Incorporate Transparent Viewing Panels: Future iterations of the dryer should include transparent viewing panels on the drying chamber to enable real-time monitoring of drying dynamics. This addition would allow operators to visually assess fish appearance and uniformity during the process, facilitating adjustments to heat or turning frequency as needed, and further improving quality control.
2. Standardize Fuel Quality: To ensure consistent performance, guidelines for fuel selection (e.g., charcoal calorific value, LPG purity) should be developed and disseminated to users. Variability in fuel quality could affect drying efficiency and sensory outcomes, so sourcing standardized inputs or integrating fuel quality sensors could enhance reliability.
3. Develop Operator Training Programs: Given the precision required to maintain optimal settings (e.g., gas pressure at 1.109 bar, six turns), training programs for operators should be established. These programs should cover equipment operation, parameter adjustment, and troubleshooting to ensure consistent results, particularly in smallholder contexts where technical expertise may be limited.
4. Integrate Renewable Energy Options: To enhance sustainability, future designs could explore integrating solar or biogas heat sources alongside charcoal and gas. This hybrid approach would reduce reliance on non-renewable fuels, lower operational costs, and align with global trends toward greener food processing technologies.
5. Conduct Cost-Benefit Analysis: A detailed economic evaluation of the optimized dryer, including fabrication costs, fuel expenses, and throughput gains, should be undertaken to quantify its viability for smallholder and commercial adoption. This analysis would provide stakeholders with actionable data to support investment decisions.

By implementing these recommendations, the rotary cage-tray fish dryer can evolve into a more user-friendly, sustainable, and widely applicable technology, amplifying its potential to reduce post-harvest losses and improve livelihoods in fish-dependent communities. This study lays a strong foundation for such advancements, offering a replicable model for optimizing food preservation systems worldwide.

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**Appendix 1: I-Optimal Optimization Solution of the Drying Machine**

| S/N | Gas Pressure | Length of fish | Weight of fish | No. of turns | Charcoal pot load | Fish appearance | Drying Time | Physical appearance | Taste and flavour | Mean temperature | Drying Efficiency | Drying Rate | Desirability |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 1.902 | 20.895 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.716 | 142.883 | 41.713 | 0.174 | 0.706 |
| 2 | 1.904 | 20.895 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.716 | 142.903 | 41.713 | 0.174 | 0.706 |
| 3 | 1.895 | 20.898 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.719 | 142.744 | 41.710 | 0.174 | 0.706 |
| 4 | 1.911 | 20.893 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.713 | 143.038 | 41.716 | 0.174 | 0.706 |
| 5 | 1.914 | 20.892 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.712 | 143.087 | 41.717 | 0.174 | 0.706 |
| 6 | 1.887 | 20.901 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.722 | 142.614 | 41.707 | 0.174 | 0.706 |
| 7 | 1.876 | 20.907 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.726 | 142.422 | 41.703 | 0.174 | 0.706 |
| 8 | 1.866 | 20.913 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.729 | 142.248 | 41.699 | 0.174 | 0.706 |
| 9 | 1.943 | 20.890 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.701 | 143.610 | 41.727 | 0.174 | 0.706 |
| 10 | 1.858 | 20.919 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.732 | 142.108 | 41.696 | 0.174 | 0.706 |
| 11 | 1.958 | 20.893 | 0.968 | 6 | two-third filled | Curve | 3 | 4.000 | 3.695 | 143.889 | 41.732 | 0.174 | 0.706 |
| 12 | 1.973 | 20.898 | 0.967 | 6 | two-third filled | Curve | 3 | 4.000 | 3.690 | 144.172 | 41.737 | 0.174 | 0.706 |
| 13 | 1.990 | 20.910 | 0.967 | 6 | two-third filled | Curve | 3 | 4.001 | 3.683 | 144.483 | 41.741 | 0.174 | 0.706 |
| 14 | 2.016 | 20.925 | 0.967 | 6 | two-third filled | Curve | 3 | 4.000 | 3.673 | 144.964 | 41.749 | 0.174 | 0.706 |
| 15 | 2.024 | 20.933 | 0.967 | 6 | two-third filled | Curve | 3 | 4.000 | 3.670 | 145.121 | 41.751 | 0.174 | 0.706 |
| 16 | 2.002 | 20.944 | 0.967 | 6 | two-third filled | Curve | 3 | 4.009 | 3.677 | 144.707 | 41.743 | 0.174 | 0.706 |
| 17 | 1.767 | 21.029 | 0.969 | 6 | two-third filled | Curve | 3 | 4.000 | 3.763 | 140.567 | 41.656 | 0.174 | 0.705 |
| 18 | 2.051 | 20.962 | 0.967 | 6 | two-third filled | Curve | 3 | 4.000 | 3.658 | 145.643 | 41.758 | 0.174 | 0.705 |
| 19 | 1.720 | 21.117 | 0.970 | 6 | two-third filled | Curve | 3 | 4.000 | 3.778 | 139.801 | 41.634 | 0.174 | 0.705 |
| 20 | 1.912 | 20.940 | 0.988 | 6 | two-third filled | Curve | 3 | 4.000 | 3.699 | 142.926 | 41.698 | 0.183 | 0.704 |
| 21 | 1.655 | 21.273 | 0.971 | 6 | two-third filled | Curve | 3 | 4.000 | 3.798 | 138.787 | 41.599 | 0.174 | 0.704 |
| 22 | 1.158 | 23.894 | 1.000 | 6 | two-third filled | Curve | 3 | 4.000 | 3.893 | 132.280 | 41.211 | 0.184 | 0.686 |
| 23 | 2.564 | 24.336 | 0.979 | 6 | two-third filled | Curve | 3 | 4.000 | 3.358 | 156.649 | 41.661 | 0.180 | 0.684 |
| 24 | 1.109 | 24.733 | 0.979 | 6 | two-third filled | Curve | 3 | 4.000 | 3.899 | 131.915 | 41.146 | 0.174 | 0.683 |
| 25 | 1.452 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.780 | 136.441 | 45.834 | 0.127 | 0.675 |
| 26 | 1.452 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.001 | 3.780 | 136.449 | 45.834 | 0.127 | 0.675 |
| 27 | 1.436 | 20.052 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.784 | 136.236 | 45.825 | 0.127 | 0.675 |
| 28 | 1.424 | 20.090 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.788 | 136.090 | 45.818 | 0.127 | 0.675 |
| 29 | 1.466 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.014 | 3.774 | 136.624 | 45.839 | 0.128 | 0.675 |
| 30 | 1.412 | 20.134 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.791 | 135.936 | 45.810 | 0.127 | 0.675 |
| 31 | 1.403 | 20.167 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.794 | 135.823 | 45.805 | 0.127 | 0.675 |
| 32 | 1.482 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.027 | 3.768 | 136.820 | 45.844 | 0.128 | 0.675 |
| 33 | 1.392 | 20.208 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.797 | 135.690 | 45.798 | 0.127 | 0.675 |
| 34 | 1.366 | 20.308 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.803 | 135.383 | 45.782 | 0.127 | 0.674 |
| 35 | 1.514 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.053 | 3.756 | 137.232 | 45.855 | 0.128 | 0.674 |
| 36 | 1.355 | 20.357 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.806 | 135.248 | 45.774 | 0.127 | 0.674 |
| 37 | 1.323 | 20.500 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.814 | 134.874 | 45.753 | 0.127 | 0.674 |
| 38 | 1.312 | 20.550 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.817 | 134.755 | 45.745 | 0.127 | 0.674 |
| 39 | 1.382 | 20.241 | 0.999 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.800 | 135.579 | 45.793 | 0.127 | 0.674 |
| 40 | 1.568 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.089 | 3.736 | 137.962 | 45.873 | 0.128 | 0.674 |
| 41 | 1.578 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.095 | 3.732 | 138.106 | 45.876 | 0.128 | 0.674 |
| 42 | 1.448 | 20.001 | 0.997 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.783 | 136.406 | 45.835 | 0.127 | 0.674 |
| 43 | 1.589 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.100 | 3.728 | 138.252 | 45.880 | 0.128 | 0.674 |
| 44 | 1.281 | 20.706 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.824 | 134.409 | 45.723 | 0.127 | 0.674 |
| 45 | 1.598 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.105 | 3.724 | 138.377 | 45.883 | 0.128 | 0.674 |
| 46 | 1.261 | 20.817 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.828 | 134.187 | 45.708 | 0.127 | 0.673 |
| 47 | 1.628 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.118 | 3.713 | 138.817 | 45.893 | 0.128 | 0.673 |
| 48 | 1.649 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.124 | 3.705 | 139.124 | 45.900 | 0.128 | 0.673 |
| 49 | 1.447 | 20.000 | 0.996 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.784 | 136.393 | 45.835 | 0.126 | 0.673 |
| 50 | 1.238 | 20.947 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.833 | 133.945 | 45.690 | 0.127 | 0.673 |
| 51 | 2.078 | 23.275 | 0.965 | 6 | full load | Curve | 3 | 4.000 | 2.675 | 176.499 | 42.464 | 0.174 | 0.673 |
| 52 | 2.071 | 23.298 | 0.965 | 6 | full load | Curve | 3 | 4.000 | 2.677 | 176.384 | 42.460 | 0.174 | 0.673 |
| 53 | 2.087 | 23.250 | 0.965 | 6 | full load | Curve | 3 | 4.000 | 2.672 | 176.628 | 42.469 | 0.174 | 0.673 |
| 54 | 2.062 | 23.329 | 0.965 | 6 | full load | Curve | 3 | 4.000 | 2.679 | 176.239 | 42.455 | 0.174 | 0.673 |
| 55 | 2.095 | 23.227 | 0.965 | 6 | full load | Curve | 3 | 4.000 | 2.670 | 176.755 | 42.474 | 0.174 | 0.673 |
| 56 | 1.242 | 20.908 | 1.000 | 9 | two-third filled | Curve | 4.5 | 3.995 | 3.833 | 133.984 | 45.694 | 0.127 | 0.673 |
| 57 | 2.050 | 23.370 | 0.965 | 6 | full load | Curve | 3 | 4.000 | 2.683 | 176.050 | 42.447 | 0.174 | 0.673 |
| 58 | 2.108 | 23.188 | 0.965 | 6 | full load | Curve | 3 | 4.000 | 2.666 | 176.971 | 42.481 | 0.174 | 0.673 |
| 59 | 1.228 | 21.009 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.835 | 133.838 | 45.682 | 0.127 | 0.673 |
| 60 | 2.040 | 23.403 | 0.966 | 6 | full load | Curve | 3 | 4.000 | 2.685 | 175.911 | 42.442 | 0.174 | 0.673 |
| 61 | 2.015 | 23.496 | 0.966 | 6 | full load | Curve | 3 | 4.000 | 2.692 | 175.534 | 42.426 | 0.174 | 0.673 |
| 62 | 2.123 | 23.162 | 0.965 | 6 | full load | Curve | 3 | 4.004 | 2.661 | 177.219 | 42.488 | 0.174 | 0.673 |
| 63 | 2.025 | 23.433 | 0.969 | 6 | full load | Curve | 3 | 4.000 | 2.688 | 175.619 | 42.432 | 0.175 | 0.673 |
| 64 | 1.693 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.134 | 3.688 | 139.775 | 45.914 | 0.128 | 0.673 |
| 65 | 2.187 | 23.014 | 0.964 | 6 | full load | Curve | 3 | 4.003 | 2.642 | 178.299 | 42.522 | 0.174 | 0.673 |
| 66 | 1.995 | 23.455 | 0.978 | 6 | full load | Curve | 3 | 4.000 | 2.693 | 175.031 | 42.413 | 0.179 | 0.673 |
| 67 | 1.193 | 21.235 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.842 | 133.476 | 45.653 | 0.127 | 0.673 |
| 68 | 2.041 | 23.199 | 0.987 | 6 | full load | Curve | 3 | 4.000 | 2.678 | 175.553 | 42.442 | 0.183 | 0.672 |
| 69 | 2.057 | 23.070 | 0.995 | 6 | full load | Curve | 3 | 4.000 | 2.671 | 175.651 | 42.451 | 0.187 | 0.672 |
| 70 | 1.178 | 21.334 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.845 | 133.332 | 45.641 | 0.126 | 0.672 |
| 71 | 2.045 | 23.100 | 0.996 | 6 | full load | Curve | 3 | 4.000 | 2.674 | 175.462 | 42.444 | 0.187 | 0.672 |
| 72 | 1.169 | 21.397 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.846 | 133.245 | 45.633 | 0.126 | 0.672 |
| 73 | 1.814 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.125 | 3.642 | 141.713 | 45.955 | 0.128 | 0.672 |
| 74 | 1.143 | 21.597 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.851 | 132.988 | 45.609 | 0.126 | 0.672 |
| 75 | 1.845 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.114 | 3.630 | 142.234 | 45.965 | 0.128 | 0.672 |
| 76 | 1.861 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.107 | 3.624 | 142.509 | 45.970 | 0.128 | 0.671 |
| 77 | 1.118 | 21.797 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.854 | 132.755 | 45.585 | 0.126 | 0.671 |
| 78 | 1.901 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.086 | 3.609 | 143.212 | 45.984 | 0.129 | 0.671 |
| 79 | 1.929 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.068 | 3.598 | 143.709 | 45.993 | 0.129 | 0.671 |
| 80 | 1.129 | 21.589 | 1.000 | 9 | two-third filled | Curve | 4.5 | 3.973 | 3.856 | 132.871 | 45.605 | 0.126 | 0.671 |
| 81 | 1.966 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.040 | 3.584 | 144.382 | 46.005 | 0.129 | 0.670 |
| 82 | 1.083 | 22.109 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.858 | 132.438 | 45.549 | 0.126 | 0.670 |
| 83 | 1.992 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.018 | 3.575 | 144.868 | 46.014 | 0.129 | 0.670 |
| 84 | 2.000 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.011 | 3.572 | 145.016 | 46.017 | 0.129 | 0.670 |
| 85 | 1.068 | 22.247 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.860 | 132.312 | 45.534 | 0.126 | 0.670 |
| 86 | 1.061 | 22.317 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.860 | 132.251 | 45.526 | 0.126 | 0.670 |
| 87 | 1.242 | 21.950 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.262 | 3.803 | 133.886 | 45.615 | 0.126 | 0.670 |
| 88 | 2.021 | 20.000 | 1.000 | 9 | two-third filled | Curve | 4.5 | 3.991 | 3.563 | 145.421 | 46.024 | 0.129 | 0.670 |
| 89 | 1.044 | 22.499 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.862 | 132.104 | 45.507 | 0.126 | 0.669 |
| 90 | 1.035 | 22.602 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.862 | 132.026 | 45.496 | 0.126 | 0.669 |
| 91 | 1.031 | 22.642 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.001 | 3.862 | 131.998 | 45.491 | 0.126 | 0.669 |
| 92 | 2.085 | 20.314 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.530 | 146.626 | 46.021 | 0.129 | 0.668 |
| 93 | 1.007 | 22.930 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.000 | 3.863 | 131.801 | 45.461 | 0.126 | 0.668 |
| 94 | 1.000 | 23.078 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.010 | 3.862 | 131.744 | 45.447 | 0.126 | 0.668 |
| 95 | 1.000 | 23.656 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.101 | 3.845 | 131.720 | 45.403 | 0.125 | 0.666 |
| 96 | 1.000 | 24.041 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.153 | 3.833 | 131.710 | 45.374 | 0.125 | 0.664 |
| 97 | 1.000 | 24.199 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.173 | 3.829 | 131.707 | 45.362 | 0.125 | 0.664 |
| 98 | 1.000 | 25.136 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.259 | 3.801 | 131.707 | 45.290 | 0.125 | 0.660 |
| 99 | 1.000 | 25.455 | 1.000 | 9 | two-third filled | Curve | 4.5 | 4.276 | 3.792 | 131.711 | 45.265 | 0.125 | 0.659 |
| 100 | 2.072 | 20.000 | 1.000 | 9 | half filled | Curve | 4.5 | 25755610944305 | 3.570 | 157.431 | 45.691 | 0.126 | 0.658 |

**For Physical appearance: 1mean Poor, 2 mean Good, 3 mean Very good and 4 mean Excellent**

**Taste and flavour: 1mean Poor, 2 mean Good, 3 mean Very good and 4 mean Excellent**