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The Development of Semi-Automatic Deboning Processing Machine for Stuffed Milkfish

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Abstract- This research project seeks to resolve issues in milkfish processing through the design, improvement, and fabrication of a specialized machine. The primary objective is to develop a milkfish processing machine capable of reducing processing time and meat loss relative to manual methods, while also enhancing the capabilities of existing deboning machines. This study employed survey questionnaires and direct observation with 13 fish vendors in Barangay Mayondon and Bayog to gather data on the time involved in separating skin and meat. Subsequently, machine testing was carried out at Laguna University, utilizing 15 milkfish samples ranging from 300 to 800 grams in weight and 30cm to 45cm in length for both skin separation and deboning evaluations. With an overall efficiency of 88.33%, the machine features an automatic skin separator that cuts processing time by over 50% and reduces meat loss by roughly two-thirds. The semi-automatic deboner processes over 128.8 kg/hour with a 51.37% yield and low 12.186% bone content. High customer satisfaction (92.3%, "Excellent") further indicates strong market potential. The Development in Semi-Automatic Deboning Processing Machine for Stuffed Milkfish represent significant progress in milkfish processing, leading to notable enhancements in efficiency, yield, product quality, and overall customer satisfaction.

I. INTRODUCTION

Milkfish (Chanoschanos) which belongs to the Family Chanidae, is an important food staple in the Philippines as it is one of the most widely consumed fish in the country. Many would recognize it for the large number of bones it contains. With this, deboning became a common practice provided by local fish sellers as a way to manage this inconvenience during consumption. This procedure makes milkfish bones one of the food wastes at disposal in local markets. However, this neglects the potential of milkfish bones as a resource as milkfish farming in the Philippines has been increasing significantly these past few years with around 400 thousand Metric Tons produced annually based on the local (figures) data provided by the Bureau of Fisheries and Aquatic Resources (BFAR) ranking second only after Indonesia [5].

Deboned milkfish or "boneless milkfish" is the most popular value-added milkfish product in the local market particularly in Luzon areas while other milkfish products produced in Luzon regions include the split-salted dried milkfish (daing na milkfish), fillets, smoked milkfish (tinapa), marinated milkfish, frozen premium cuts (belly), stuffed milkfish (relleno), and bottled milkfish. [6]

According to the research, with labor shortages, the necessity for automation in cutting and deboning is growing, however it is not yet as common than the well-known pay for labor. This statement is changing as labor expenses rise, including those for worker's compensation, insurance, and medical care. Automated systems also provide the benefits of speed, efficiency, and worker safety while also not taking vacations or calling in sick. [8]

The demand for stuffed milkfish is increasing, which means there is a need for a faster and more efficient way to process it. Traditional methods of deboning are slow, require a lot of effort, and often lead to uneven results, making it hard for producers to keep up. Developing a semi-automatic deboning machine will help solve this problem by speeding up the process, making it easier to produce more fish in less time while keeping the quality consistent. This project would simplify, improve the efficiency, and make deboning much easier.

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A. Objectives of the Study

To develop a semi-automatic deboning processing machine for stuffed milkfish.

Specific objectives

1. Compare the machine's designed skin separator mechanism with manual skin separator method focusing on:

1.1 time taken to separate skin from dressed fish

1.2 accuracy

2. To test and evaluate the performance of the machine compare to the existing meat and bone separating machine in terms of:

2.1 capacity

2.2 yield percentage

2.3 bone content

3. Determine the efficiency of semi-automatic deboning processing machine for stuffed milkfish in terms of:

3.1 the quality of the minced milkfish meat

B. Scope and Limitations of Research

The skin separator and deboning machine are specifically designed for small-scale production of milkfish (30 to 45 cm long, 300 to 800 grams in weight) and are not intended for other seafood, industrial applications, or taste control. The machine extracts bones, with expected yields between 9% and 15% of the fish's total weight, though complete removal is not guaranteed. The project does not cover processing beyond skin separation and deboning.

The skin separator processes one milkfish at a time at a constant speed of 20.4 rotations per minute via an On/Off push-button. It utilizes a detachable, 21 cm spatula with a 20 cm linear travel distance for easy cleaning and sanitation. Before use, the milkfish requires manual preparation, including pounding, snapping the backbone near the tail fin in half, and removing the viscera, gills, fins, and scales. Post-processing meat extraction from the skin is not automated and must be done manually.

The meat and bone-separating machine also processes one fish at a time, utilizing a perforated drum with 5 mm holes operating at a fixed 20.5 revolutions per minute to output strictly minced meat. The belt-to-drum contact is set at 45% and is adjustable via Roller Adjustment Bolts. For maintenance, the drum, belt, and rollers are detachable, and the control panel includes an on/off button and an emergency stop button. This machine requires manual feeding, meaning the operator must dress the fish (removing viscera, fins, gills, scales, and skin) and manually place the meat vertically at the conveyor belt inlet.

II. RESEARCH METHODOLOGY

A. Research Design

The researchers employed two methods in this study: the survey method and the developmental method of research. To gather the necessary data and information, a survey was conducted in wet markets near Laguna de Bay using convenience sampling. The survey focused on the procedures and time involved in the traditional method of milkfish meat and skin separation. From this, the efficiency and average speed of the manual separation method were obtained.

The developmental research method was also used. In this case, the researchers initially gathered data through surveys and reviewed related studies and literature. Based on these findings, the researchers established the objective of designing a semi-automatic deboning process to improve the capacity and efficiency of milkfish deboning.

B. Process Flow Chart of the Study

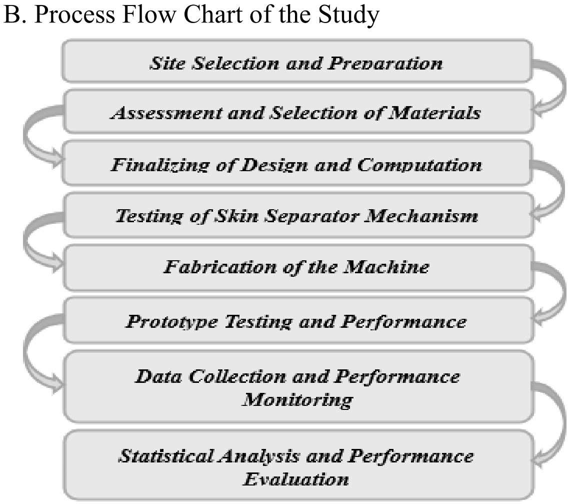

Figure 1: Process Flow Chart of the Study

Site Selection and Preparation:
The study focused on Barangays Bayog and Mayondon in Los Baños City, Laguna, due to their proximity to Laguna Lake, a significant source of milkfish. Los Baños is important because it has the second-highest number of operators in the area, with 58 operators, just behind Biñan, which has 76 operators [3]. Laguna Lake is a major aquaculture area, providing a substantial portion of milkfish consumed in Metro Manila, and Los Baños has a high number of fish operators.

Assessment and Selection of Materials:
Materials were selected based on market availability and cost, with a primary focus on food-grade stainless steel (Grade 304) for parts in direct contact with fish due to its corrosion resistance and hygienic properties. Key components included a perforated drum (5mm holes) and a 2-ply food-grade conveyor belt, a 1.5kW/2Hp single-phase electric motor, and a speed reduction gearbox (1:80 ratio).

Finalizing of Design and Computation:
The machine's design was conceptualized to streamline skin separation and deboning, aiming to increase productivity and income for fish vendors. Fusion360 software was used for CAD design, providing isometric, front, side, top, and exploded views. Detailed engineering computations were performed for components like the hopper, drum, slider crank, shaft, and conveyor belt to ensure proper functionality and adherence to standards (ISO, PAES, PNS).

Fabrication of the Machine:
The machine was fabricated using selected food-grade materials, prioritizing operator and equipment safety. Features included accessible emergency buttons, warning labels, insulated and waterproofed electrical components, and smooth, easy-to-clean surfaces. The design focused on minimizing meat loss, maximizing yield, providing sufficient processing capacity, and ensuring user-friendly operation and maintenance. The perforated drum speed was set to 20.5 rpm, and the spatula for skin separation was designed to be detachable and reinforced.

Prototype Testing and Performance Evaluation:
Initial tuning of the skin separator involved evaluating different blade designs to optimize quality, accuracy, and operational speed. Performance testing for both the skin separator and deboning machine involved processing milkfish samples (300-800 grams, 30-45 cm length).

Data Collection and Performance Monitoring:
Primary data was collected through surveys (Likert scale) and direct observation/case studies. Videos were used to record processing times for manual methods, which were then compared with the semi-automatic machine's performance. Data on meat loss, processing capacity, yield percentage, and bone content were precisely timed and recorded.

Statistical Analysis and Performance Evaluation:
Survey responses were analyzed using the Central Tendency of the Median and the Dispersion of the Interquartile Range (IQR). Likert scales (5-point) were used for interpretation. Customer Satisfaction Score (CSAT) was calculated, focusing on "Satisfied" and "Very Satisfied" responses. Cronbach's alpha was used to assess the reliability of the survey questionnaire. Machine performance data (time, accuracy, capacity, yield, bone content) were analyzed statistically and compared against established benchmarks and manual methods.

A. Machine Design

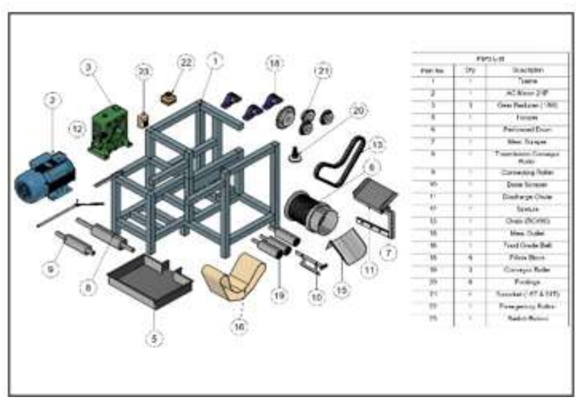

Figure 2. Exploded View of the Semi-Automatic Deboning Processing Machine

Figure 2 shows an exploded view and parts list of the machine, primarily designed for deboning. The key component for this process is the perforated drum, featuring 5 mm diameter holes, which functions to separate fish meat from bones. Mechanical power is supplied by a 2HP AC Motor (2) and a 1:80 Gear Reducer (3), which drive the food-grade belt (16) via a system of sprockets (21), an RC60 chain (13), pillow blocks (18), and conveyor rollers (8, 9, 19) mounted on the frame (1) with footings (20). The assembly includes a hopper (5) and spatula (12) for input, a meat scraper (7) and bone scraper (10) and a discharge chute (11) and meat outlet (15) for collection. Operational safety is managed through an integrated switch button (23) and an emergency button (22).

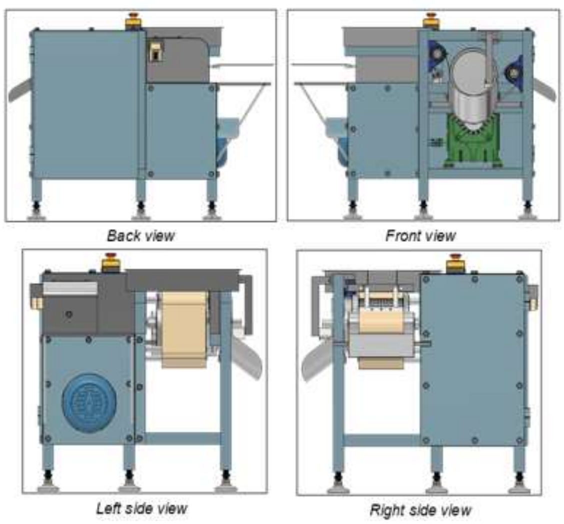

Figure 3. Technical Design of Semi-Automatic Deboning Processing Machine

Figure 3 shows the back view, front view, left side view, and right side view of the Semi-Automatic Deboning Processing Machine.

III. RESULTS

Survey Results

Table 1: Overall tally

Overall Tally		
Question 1	Which method do you currently use to process milkfish for stuffed milkfish production?	
Choices	Frequency	Percentage
Manual method	13	100%
Machine-operated method	0	0
Total	13	100%
Question 2	How many milkfish do you typically process or sell daily?	
5 - 10	3	23.08%
11 - 15	3	23.08%
16 - 20	3	23.08%
21 - 25	0	0
26 & above	4	30.77%
Total	13	100%
Question 3	What is your processing fee per stuffed milkfish?	
10 pesos & below	2	15.38%
11 - 20 pesos	2	15.38%
21 - 30 pesos	3	23.08%
31 - 40 pesos	5	38.46%
41 pesos & above	1	7.69%
Total	13	100%
Question 4	How long does it usually take to separate the skin from the meat when processing stuffed milkfish?	
30 seconds & below	0	0
31 - 60 seconds	0	0
61 - 90 seconds	0	0
91 - 120 seconds	1	7.69%
121 seconds & above	12	92.31%
Total	13	100%
Question 5	How would you rate the quality of the ground meat produced by a milkfish deboning machine?	
Very Satisfied	8	61.54%
Satisfied	4	30.77%
Neutral	1	7.69%
Dissatisfied	0	0
Very	0	0

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Dissatisfied		
Total	13	100%

Question 6	In your experience, what are the main challenges in using a deboning machine? (Not Applicable)	
High cost of the machine	0	0
Difficult to operate	0	0
Maintenance issues	0	0
Limited availability	0	0
Other	0	0
Total	0	0
Question 7	Would you be interested in a machine that can both separate the skin and debone a milkfish?	
Yes	12	92.31%
No	1	7.69%
Total	13	100%
Question 8	What features would you like to see in a semi-automatic deboning machine?	
Faster processing time	8	61.54%
Higher meat quality	0	0
Easier operation	3	23.08%
More affordable	2	15.38%
Other	0	0
Total	13	100%
Question 9	Would you be open to training on how to use a new deboning machine?	
Yes	12	92.31%
No	1	7.69%
Total	13	100%

Question 10	Do you believe that a semi-automatic deboning machine can improve your production and income?	
Strongly Agree	11	84.62%
Agree	1	7.69%
Neutral	0	0
Disagree	1	7.69%
Strongly Disagree	0	0
Total	13	100%

Table 1 presents the structured survey questions, the corresponding response choices, and the frequency distribution along with the percentage breakdown of the participants' answers.

- Time Spent in Processing Stuffed Milkfish Using Manual Method

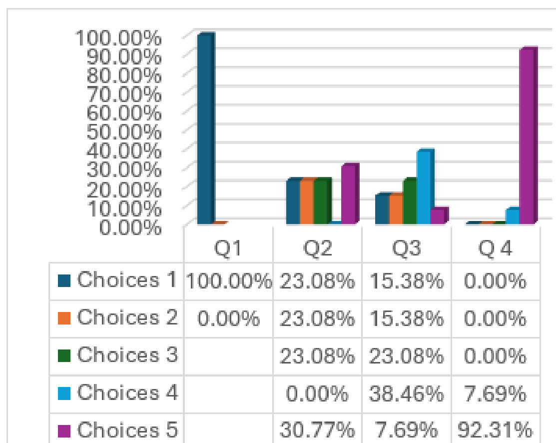

Figure 4: Experience with Manual Processing

Manual Processing Experience: 100% of surveyed fish vendors used manual methods for milkfish processing. 92.31% reported that skin separation manually takes 121 seconds or more per fish, indicating it is a time-consuming process.

- Quality of Minced Meat Using Semi-Automatic Deboning Machine

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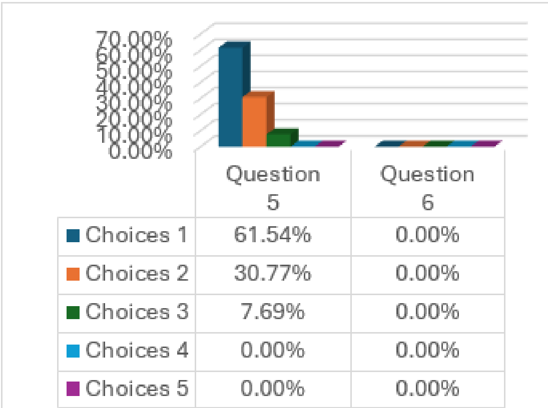

Figure 5: Experience with Semi-Automatic Deboning Machine for Stuffed Milkfish

Semi-Automatic Deboning Machine Quality: 61.54% of respondents were "Very Satisfied" and 30.77% were "Satisfied" with the quality of ground meat produced by a milkfish deboning machine (total 92.31% positive satisfaction).

- Level of Interest in a Semi-Automatic Deboning Machine for Stuffed Milkfish

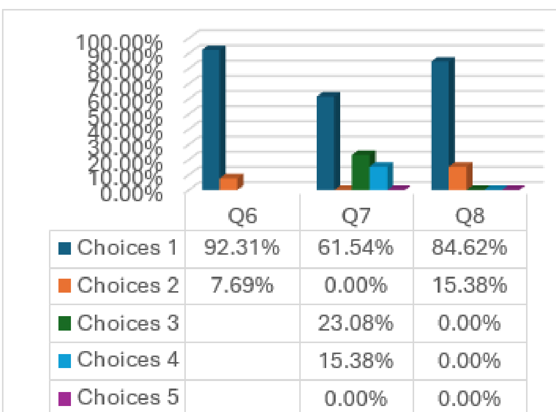

Figure 6: Level of Interest in a Semi-Automatic Deboning Machine for Stuffed Milkfish

Interest in Semi-Automatic Machine: 92.31% of respondents expressed interest in a machine that can both separate skin and debone milkfish. 61.54% prioritized "Faster processing time" as a desired feature. 84.62% were willing to invest less than ₱30,000.

- Readiness to Attend Training Regarding Automatic Machine

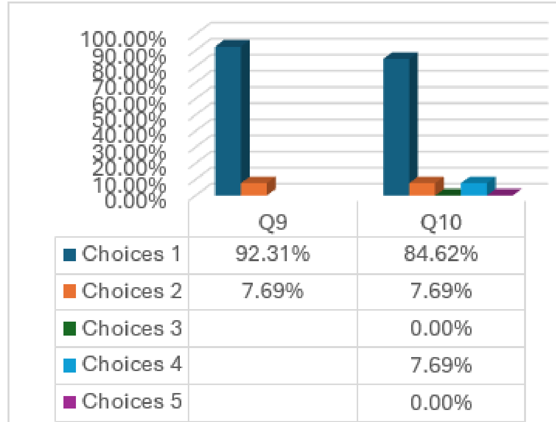

Figure 7: Readiness in Attending Training

Readiness for Training: 92.31% were open to training on a new deboning machine. 84.62% "Strongly Agreed" that a semi-automatic deboning machine could improve their production and income.

Table 2: Cron Bach's Alpha Analysis for Survey Questionnaire

	Q1	Q2	Q3	Q4	Q5	Q6
1	5	1	2	5	5	5
2	5	2	1	5	4	5
3	5	5	1	5	3	1
4	5	2	4	5	4	5
5	5	3	3	4	5	5
6	5	1	3	5	5	5
7	5	5	4	5	5	5
8	5	3	4	5	4	5
9	5	5	5	5	5	5
10	5	3	3	5	5	5
11	5	5	4	5	4	5
12	5	2	2	5	5	5
13	5	5	4	5	5	5
	0	2.33	1.46	0.07	0.40	1.14

	Q7	Q8	Q9	Q10	SUM
1	5	5	5	5	43
2	5	5	5	4	41
3	2	5	1	2	30
4	3	5	5	5	43
5	5	5	5	5	45
6	2	5	5	5	41

7	5	5	5	5	49
8	2	5	5	5	43
9	5	5	5	5	50
10	5	5	5	5	46
11	5	4	5	5	47
12	3	5	5	5	42
13	5	4	5	5	48
	1.69	0.13	1.13	0.67	23.91

Table 2 shows the responses of 13 participants to 10 questions, the variance of the total scores was found to be 23.9053. The sum of the individual item variances was 9.0296. The resulting Cronbach's alpha coefficient of 0.69142 suggests "Acceptable" consistency in the tests and measures employed in this study.

Figure 8: CSAT Rating of Question 5

The CSAT score is calculated by dividing the number of positive responses (12) by the total number of responses (13) and multiplying by 100%. This calculation results in a CSAT score of 92.3%, indicating a very high level of customer satisfaction. The Figure 8 revealed a Customer Satisfaction (CSAT) score of 92.3% for the quality of ground meat produced by a milkfish deboning machine. In this specific industry, a CSAT score of 79% is considered a typical benchmark for good customer satisfaction. The customer satisfaction (CSAT) score for the ground meat, recorded at 92.3% and categorized as "excellent," significantly surpasses the industry benchmark.

The customer satisfaction (CSAT) score for the ground meat, recorded at 92.3% and categorized as "excellent," significantly surpasses the industry benchmark. This indicates that the respondents' perception of the ground meat's quality is not merely satisfactory but is exceptionally positive, far surpassing the average expectations within the industry. It strongly suggests that the milkfish deboning machine is performing at a level that is considerably higher than the industry standard.

Machine Testing Results

Table 3: Machine's Skin Separator Results

#	Gross Weight (g)	Time Taken for Skin Separation (s)	Remarks
1	685	64	Acceptable
2	630	63	Acceptable
3	540	45	Acceptable
4	560	75	Acceptable
5	460	67	Acceptable
6	570	44	Acceptable
7	620	60	Acceptable
8	580	54	Acceptable
9	580	39	Acceptable
10	740	64	Acceptable
11	695	58	Acceptable
12	740	50	Acceptable
13	765	58	Acceptable
14	530	65	Acceptable
15	740	57	Acceptable
Average	629g ± 93.49g	57.53s ± 9.72s	Acceptable

The table 3 shows the performance of a skin separator machine in removing fish skin. The skin separation process took an average of 57.53s ± 9.72s per sample. Considering the tolerance, the skin separation of a single sample is expected to take anywhere between approximately 47.81 seconds and 67.25 seconds. This was considered 'Acceptable' based on survey data indicating that the manual method typically takes 121 seconds or more. The consistency in processing time suggests that the machine is efficient and reliable for fish processing operations, making it a suitable choice for improving productivity.

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Table 4: Machine's Capacity for Deboning Results

#	Fish Meat Weight (g)	Time Taken for Deboning (s)	Production Rate (g/s)	Production Rate (kg/min)	Remarks
1	365	8	45.63	2.74	Acceptable
2	370	9	41.11	2.47	Acceptable
3	300	7	42.86	2.57	Acceptable
4	310	8	38.75	2.33	Acceptable
5	230	8	28.75	1.73	Acceptable
6	320	8	40.00	2.40	Acceptable
7	350	12	29.17	1.75	Acceptable
8	315	9	35.00	2.10	Acceptable
9	345	8	43.13	2.59	Acceptable
10	435	12	36.25	2.18	Acceptable
11	355	15	23.67	1.42	Acceptable
12	425	15	28.33	1.7	Acceptable
13	430	11	39.09	2.35	Acceptable
14	305	13	23.46	1.41	Acceptable
15	410	10	41.00	2.46	Acceptable
Ave			35.7467g/s	2.1467kg/min	Acceptable

Table 4 shows that the deboning machine achieved an average rate of 2.1467 kg/min, or 128.8 kg/hr—equivalent to processing around 366 fish per hour based on an average fish meat weight of 351g. This performance exceeds the existing machine's capacity of 80 kg/hr [1], indicating that the developed machine is efficient of handling varying sample sizes with consistent output.

Table 5: Fish Yield Percentage Results

#	Mince Meat Recovered (g)	Dressed Weight (g)	Yield Percentage (%)	Remarks
1	230	610	37.70	Rejected
2	320	550	58.18	Acceptable
3	250	475	52.63	Acceptable
4	245	495	49.49	Acceptable
5	200	400	50.00	Acceptable
6	260	485	53.61	Acceptable
7	275	530	51.89	Acceptable
8	255	500	51.00	Acceptable
9	280	505	55.45	Acceptable
10	355	645	55.04	Acceptable
11	300	600	50.00	Acceptable
12	360	665	54.14	Acceptable
13	350	675	51.85	Acceptable
14	240	470	51.06	Acceptable
15	320	660	48.48	Acceptable
Ave	282.67 ± 49.35g	551g ± 85.68g	51.37% ± 4.58%	Acceptable

Table 5 shows an average yield of 51.37% ± 4.58%, with most samples falling within the acceptable range of (40.74%-49.30%) [7]. Sample #1 was rejected for having a low yield (37.70%) due to meat sticking to

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the drum. Similar findings in previous studies noted lower recovery in first passes, which improved with repeated processing [2]. Overall, the results confirm the machine's effectiveness in meat recovery, with occasional inconsistencies that should be monitored.

Table 6: Fish Bone Content Results

#	Fish Bone Weight (g)	Gross Weight (g) * 0.5	Bone Content (%)	Remarks
1	45	685	13.14	Acceptable
2	35	630	11.11	Acceptable
3	35	540	12.96	Acceptable
4	30	560	10.71	Acceptable
5	30	460	13.04	Acceptable
6	30	570	10.53	Acceptable
7	45	620	14.52	Acceptable
8	40	580	13.79	Acceptable
9	30	580	10.34	Acceptable
10	40	740	10.81	Acceptable
11	55	695	15.83	Acceptable
12	35	740	9.46	Acceptable
13	50	765	13.07	Acceptable
14	30	530	11.32	Acceptable
15	45	740	12.16	Acceptable
Ave	38.33g ± 8.16g	629g ± 93.49g	12.186% ± 1.77%	Acceptable

The table 6 shows the amount of bone in 15 fish samples. The bone content was calculated by dividing the fish bone weight by 50% of the fish's total weight. The 50% comes from the average of the usual fish waste range (20% to 80%) [4]. The average bone content percentage for each sample is 12.186% ± 1.77%. Based on the PMC standard, the acceptable percentage of bone content is between 9% and 15% [4]. All the samples are marked as "Acceptable."

Table 7: Machine's Accuracy Results

#	Fish Meat Weight (g)	Skin Leftover Meat (g)	Meat Loss (%)	Remarks
1	365	15	4.11	Acceptable
2	370	20	5.41	Acceptable
3	300	10	3.33	Acceptable
4	310	10	3.23	Acceptable
5	230	10	4.35	Acceptable
6	320	15	4.69	Acceptable
7	350	15	4.29	Acceptable
8	315	15	4.76	Acceptable
9	345	15	4.35	Acceptable
10	435	10	2.30	Acceptable
11	355	25	7.04	Acceptable
12	425	15	3.53	Acceptable
13	430	10	2.33	Acceptable
14	305	10	3.28	Acceptable
15	410	10	2.44	Acceptable
Ave	351g ± 57.42g	13.67g ± 4.42g	3.96% ± 1.27%	Acceptable

Table 7 shows that the machine achieved an average meat loss of 3.96% ± 1.27%, with all 15 samples ranging from 2.30% to 7.04% and marked as 'Acceptable.' This indicates efficient meat separation with minimal waste, significantly better than the 11.61% average meat loss seen in manual processing.

Table 8: Manual's Accuracy Results

#	Fish Meat Weight (g)	Skin Leftover Meat (g)	Meat Loss (%)	Remarks
1	335	50	14.93	Acceptable
2	270	20	7.41	Acceptable
3	290	25	8.62	Acceptable
4	360	20	5.56	Acceptable
5	175	45	25.71	Acceptable
6	240	25	10.42	Acceptable
7	85	10	11.76	Acceptable
8	310	20	6.45	Acceptable
9	375	30	8	Acceptable
10	415	60	14.46	Acceptable
11	295	25	8.47	Acceptable
12	270	45	16.67	Acceptable
13	200	25	12.5	Acceptable
Ave	278.46g ± 85.54g	30.77g ± 13.98g	11.61% ± 5.25%	Acceptable

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Table 9 details skin separator efficiency by measuring meat loss. An average of 351g ± 57.42g of fish meat was processed, with just 13.67g ± 4.42g of meat remaining on the skin after separation. This small amount of leftover meat yields a high skin separator efficiency of 96.11%, showing precise separation and effective reduction of product loss during processing.

Table 10: Efficiency of Deboning Machine (Yield Percentage)

#	Existing Deboning Machine	Developed Deboning Machine	Efficiency
1	45.02%	37.70%	83.74%
2	45.02%	58.18%	77.38%
3	45.02%	52.63%	85.54%
4	45.02%	49.49%	90.97%
5	45.02%	50.00%	90.04%
6	45.02%	53.61%	83.98%
7	45.02%	51.89%	86.76%
8	45.02%	51.00%	88.27%
9	45.02%	55.45%	81.19%
10	45.02%	55.04%	81.80%
11	45.02%	50.00%	90.04%
12	45.02%	54.14%	83.15%
13	45.02%	51.85%	86.83%
14	45.02%	51.06%	88.117%
15	45.02%	48.48%	92.86%
Ave	45.02%	51.37%	87.64%

Table 10 compares the average yield percentage of an existing deboning machine (45.02%) with a developed deboning machine (consistently 51.37%), revealing an average efficiency of 87.64% for the developed machine in improving yield; this significant gain in meat recovery from the same input demonstrates the developed machine's greater processing efficiency and its effectiveness in maximizing product yield compared to the existing technology.

Table 11: Efficiency of Deboning Machine (Bone Percentage)

Parameter	Target Bone Percentage	Developed Machine	Efficiency
1	15%	13.14%	87.6%
2	15%	11.11%	74.07%
3	15%	12.96%	86.40%
4	15%	10.71%	71.40%
5	15%	13.04%	86.93%
6	15%	10.53%	70.20%
7	15%	14.52%	96.80%
8	15%	13.79%	91.93%
9	15%	10.34%	68.93%
10	15%	10.81%	72.07%
11	15%	15.83%	94.76%
12	15%	9.46%	63.07%
13	15%	13.07%	87.13%
14	15%	11.32%	75.47%
15	15%	12.16%	81.07%
Bone Percentage	15%	12.186%	81.24%

Table 11 details the efficiency of a developed deboning machine in achieving a target bone percentage. The target bone percentage was set at 15%, while the developed machine achieved an average bone percentage of 12.186%. The calculated efficiency, representing the developed machine's success in reducing bone content towards the target, is 81.24%. This indicates that the developed machine demonstrates a considerable ability to minimize bone residue in the processed meat, reaching 81.24% of the desired bone reduction level.

Table 12: Overall Efficiency of the Machine

Parameter		Efficiency
Skin Separator		96.11%
Deboning Machine	Yield Percentage	87.64%
	Bone Percentage	81.24%
Overall Machine's Efficiency		88.33%

Table 12 presents the overall efficiency of the machine, broken down by its key components: the skin separator and the deboning machine. The skin separator demonstrates a high efficiency of 96.11%. For the deboning machine, two aspects of efficiency are considered: yield percentage, which stands at

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87.64%, and bone percentage, which shows an efficiency of 81.24% in meeting the target. Combining these individual efficiencies, the overall efficiency of the entire machine is calculated to be 88.33%, indicating a strong integrated performance across its processing stages.

IV. DISCUSSION

The research successfully addressed the limitations of traditional milkfish processing by developing a semi-automatic deboning machine with an integrated skin separator. The findings demonstrate significant improvements in efficiency, yield, and product quality compared to manual methods and existing machines.

The skin separator mechanism proved highly effective, reducing processing time per fish by over 50% (from 121+ seconds manually to 57.53 seconds with the machine). This substantial time saving directly addresses the labor-intensive nature of manual skinning, a key problem identified in the background. Furthermore, the machine's accuracy, indicated by an average meat loss of only 3.96%, is a significant improvement over the 11.61% meat loss observed in manual processing. This reduction in waste directly contributes to higher profitability for producers, aligning with the study's significance in practice. The observation that manual scraping leads to higher meat loss due to slippage and hand fatigue further validates the need for automation.

The semi-automatic deboning machine demonstrated superior performance in terms of capacity. Its processing rate of 128.8 kg/hr significantly surpasses the 80 kg/hr capacity of existing machines, indicating a substantial increase in productivity. While one sample showed a lower yield percentage (37.70%) due to meat sticking, the average yield of 51.37% for milkfish is comparable to or slightly better than the 49.30% reported for existing machines. This suggests that with further optimization like improved scraping techniques as noted in the results, the machine's yield can be consistently maximized. The consistently low bone content of 12.186% (within the 9-15% target range) confirms the machine's effectiveness in producing high-quality, boneless minced meat, which is crucial for consumer satisfaction and product marketability.

The high customer satisfaction score (CSAT) of 92.3%, categorized as "Excellent," strongly indicates the market potential and acceptance of the developed machine's output. This level of satisfaction, significantly above the industry benchmark of 79%, suggests that the machine effectively meets or exceeds consumer expectations for deboned milkfish quality. This positive reception validates the overall objective of enhancing product quality and consumer experience.

Overall, the machine's combined efficiency of 88.33% (derived from 96.11% for the skin separator, 87.64% for deboning yield, and 81.24% for bone percentage) underscores its strong integrated performance.

V. CONCLUSIONS

The following conclusions are drawn:

1. The developed semi-automatic deboning processing machine significantly improves efficiency in milkfish processing. The automatic skin separation method reduces processing time by over 50% and decreases meat loss by approximately two-thirds compared to manual methods.
2. The machine demonstrates superior performance over existing deboning machines, achieving a higher processing capacity of over 128.8 kg of fish per hour. It also maintains a good meat recovery yield of 51.37% and consistently produces minced meat with a low bone content of 12.186%, meeting established standards.
3. The quality of deboned milkfish meat produced by the machine achieved an "Excellent" customer satisfaction score of 92.3%, indicating strong market potential and consumer acceptance.
4. The overall efficiency of the developed machine is 88.33%, reflecting high performance across its skin separation (96.11%) and deboning (87.64% yield, 81.24% bone removal) stages.

VI. RECOMMENDATIONS

Below are the recommendations proposed by the proponents based on the results of the conducted testing on the prototype:

- Future researchers can integrate a roller press to automatically extract the meat from the skin after the skin separation process.
- Future researchers can increase the length of the perforated drum to allow more fish to pass through at once.
- Future researchers can increase the width of the spatula to speed up the operation of the skin separator.
- Future researchers can include a clutch system to reduce the load on the motor, and a VFD speed controller.

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