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# CONFIGURING A VACUUM TUMBLER MACHINE FOR MARINATING MEAT USING AXIOMATIC DESIGN METHODOLOGY

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***Abstract:*** *Vacuum marination is an advanced technique used to accelerate the absorption of marinades into meat, enhancing flavor, tenderness, and moisture retention. This process utilizes a vacuum environment to force the marinade deep into the muscle fibers by eliminating air pockets and opening up the meat's structure. A vacuum tumbler is a specialized machine designed to accelerate the marination process of meat, poultry, and seafood by applying vacuum pressure while gently tumbling the product. The goal of the work is to design a vacuum tumbler machine that ensures uniform, efficient, and high-quality marination of meat within a controlled environment. Axiomatic Design (AD) provides a systematic approach to designing a Vacuum Tumbler Machine for Marinating Meat, ensuring efficiency, performance, and usability.*

***Key words:*** *high-quality marination of meat, vacuum marination, vacuum tumbler, Axiomatic Design (AD).*

## 1. INTRODUCTION

The vacuum tumbler is an essential machine in the meat processing industry, widely used to enhance product quality through improved marinade absorption, texture modification, and moisture retention. By utilizing mechanical action under vacuum conditions, this technology facilitates protein extraction, increases binding properties, and ensures uniform seasoning distribution. While existing vacuum tumblers have demonstrated significant advantages in meat processing, their design can still be optimized to improve efficiency, adaptability, and energy consumption.

This study aims to design a novel vacuum marination tumbler using the Axiomatic Design approach. By applying this systematic design methodology, we seek to develop a machine that optimizes functional requirements, enhances process efficiency, and ensures a more consistent marination effect. Through this research, we aim to address current limitations in vacuum tumbling technology and propose an innovative solution tailored to industrial meat processing needs.

## 2. PROBLEM DESCRIPTION

Current household vacuum marination machines are limited in their ability to achieve sufficient vacuum levels, which restricts the efficiency of the marination process and affects the final quality of the products. Additionally, most existing models lack adaptability, offering minimal flexibility in accommodating different container sizes, controlling internal pressure, or adjusting the rotation speed during operation. These limitations make it difficult for users to achieve consistent and high-quality results, particularly when marinating a variety of food types under varying conditions. Therefore, there is a need for a more versatile and efficient vacuum marination solution tailored for domestic use.

## 3. APPLICATION FIELD

The designed vacuum marination machine is primarily intended for applications within the food processing industry, particularly in small-scale meat processing facilities, restaurant kitchens, and household environments. It offers an efficient solution for accelerating the

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marination process, enhancing flavor absorption, and improving the texture of various meat products. Additionally, the machine can be adapted for use in laboratory testing environments where controlled marination conditions are required for research purposes. Its modular construction and adjustable operating parameters allow it to be integrated into broader food preparation systems, providing flexibility for both experimental setups and industrial pilot lines.

## 4. RESEARCH METHOD

The research method involved compiling a comprehensive library of journal articles, conference papers, books, patents, and company catalogs to systematically structure ideas and solutions related to the vacuum tumbler. These sources provided a broad perspective on the design, functionality, and optimization of vacuum tumbling technology.

To organize the gathered information, an idea matrix or diagram was developed (see Table 1), facilitating comparative analysis of various vacuum tumbler solutions. Contrastive evaluations were conducted, highlighting the strengths and limitations of different designs. Through this investigation, recurring concepts and technical approaches were identified across multiple sources, confirming the consistency and relevance of key engineering principles in vacuum tumbling.

Based on this synthesis of ideas, the four domains (Customer Needs, Functional Requirements, Design Parameters, Process Variables) necessary for applying the Axiomatic Design methodology in the design of a new solution can be defined.

Axiomatic Design methodology was used to configure a new vacuum tumbler machine for marinating meat solution.

## 5. INVESTIGATING AND ORGANIZING EXISTING SOLUTIONS

This section provides an overview of the documentation sources utilized in this study and structures the solutions into a diagram/matrix of ideas.

The first source with reference to vacuum tumbler was identified in a patent [1] (Table 1, Position 1.1) and presents a rear-end adjustable vacuum tumbler designed to improve the efficiency of meat marination. Unlike traditional horizontal tumblers, which complicate discharging and cleaning due to meat accumulation and poor drainage, this design features a tiltable cylinder supported by a sliding seat and hinged frame. It allows for easy discharge of contents and better stability during operation. The vacuum system ensures thorough marination by enhancing absorption, texture, and product quality, while the structure minimizes machine height for easier handling and maintenance.

Folowing patent [2] (Table 1, Position 2.1) introduces a vacuum tumbler for food processing that includes an integrated cooling system to maintain low temperatures (0–4 °C) during operation. The design includes features such as spiral vanes for effective tumbling, a vacuum extraction system, andoptional components like a frequency converter and filter.

Solution [3] (Table 1, Position 3.1) presents a method and apparatus for continuous vacuum marination of food products. The system continuously monitors input and output weights, using this data to adjust cycle timing and maintain optimal retention time.

Patent [4] (Table 1, Position 4.1) presents an improved vacuum tumbler for pickling fish, designed to enhance hygiene and efficiency in aquatic product processing. The design ensures thorough internal cleaning, prevents contamination of cleaning components, and improves the overall quality and consistency of fish pickling. Additional features include a heating mechanism, discharge system, and structural enhancements for better performance and ease of use.

Patent [5] (Table 1, Position 5.1) introduces a vacuum tumbler designed to enhance the marination of food products by alternately exposing them to marinating liquid and partial vacuum. The device consists of a vacuum-sealable container, an internal rib or shelf, a drive mechanism, and a vacuum source. As the container rotates—or as the internal shelf moves—the food is repeatedly lifted out of the

liquid and into the vacuum zone, improving flavor absorption and marination efficiency. The method and device are intended to improve marination speed, flavor penetration, and can be applied to both new and retrofitted equipment.

In another patent [6] (Table 1, Position 6.1) is presented an evacuated refrigeration tumbler designed for meat processing. These additions accelerate cooling, maintain optimal temperatures during operation, and improve the product's quality, elasticity, and texture by ensuring more efficient tumbling and uniform pickling.

Solution [7] (Table 1, Position 7.1) introduces a fully automatic, variable-frequency vacuum tumbler specifically designed for marinating vegetables. It features an integrated vacuum system with a getter pump to efficiently remove air and prevent oxidation, improving the quality of marination. The device also includes an automated discharging mechanism using a sliding cover and support plate for easier vegetable removal. A modular sealing system with removable choker blocks ensures easy maintenance and airtight performance, enhancing hygiene, usability, and operational efficiency over traditional tumblers.

The patent [8] (Table 1, Position 8.1) introduces an improved marinating device designed to securely retain a food container in place during rotation, ensuring safe and effective marination. It also includes a retractable vacuum tube stored within the base, protecting it from damage in kitchen environments.

The patent [9] (Table 1, Position 9.1) relates to a pickling device designed specifically for marinating duck products, addressing issues with flavor absorption in foods like duck, which are typically hard to marinate effectively. The device includes a barrel with a stirring rod system inside, which mimics the manual process of pricking holes in the food, allowing the marinade to penetrate deeply. The device consists of several components such as a motordriven stirring mechanism, a vacuum suction nozzle, and a cover, ensuring efficient and uniform pickling. The design improves the flavor and tenderness of difficult-to-marinate meats by allowing for better absorption of the pickling brine, solving the problem of poor taste in foods like duck.

The next invention [10] (Table 1, Position 10.1) introduces a vacuum tumbler that uses a water circulation vacuum pump instead of traditional oil-based systems. The device is primarily designed for marinating and tenderizing meat under vacuum conditions, enhancing protein interaction, texture, and moisture retention. The setup includes a rotating drum, a sealed air pathway, and a closed-loop water circulation system that generates negative pressure, making it ideal for safe and efficient meat processing.

The patent [11] (Table 1, Position 11.1) is about an improved marination drum apparatus designed to streamline the preparation of marinated chicken in commercial food settings. The drum is rotatable via a drive axle, with structural features that allow controlled directional rotation. This design enhances efficiency by reducing the time required for separating and preparing chicken pieces during marination

The patent [12] (Table 1, Position 1.2) describes a vacuum sealed tumbler designed for storing and transporting food over extended periods. The tumbler includes a main container with a detachable lid, a sealable outlet, and an integrated manual pump system. A check valve and sealing rings ensure airtight conditions, while the pump allows air to be removed from the interior to create a vacuum.

In the following patent [13] (Table 1, Position 2.2) is presented a vacuum smoking tumbler designed to streamline the food marination process by combining vacuum smoking and sauce mixing in a single device. The system includes a rotating, vacuum sealable chamber connected to both a smoke compressor and a vacuum compressor, enabling food ingredients to be smoked under vacuum conditions and then immediately mixed with sauce.

The invention [14] (Table 1, Position 3.2) presents a vacuum tumbler designed to maintain hygiene and preserve beverage quality by preventing contamination and oxidation. It features a vacuum-sealing system operated by a pumping mechanism, which removes air from the container. An innovative vacuum release

system allows for easy opening, while an internal air layer formed when tilted prevents liquid from entering the pump, ensuring smooth function.

The patent [15] (Table 1, Position 4.2)introduces a vacuum tumbler designed for storing beverages in a vacuum-sealed environment, enhancing freshness and preventing oxidation. The structure effectively prevents leakage and ensures convenient storage and consumption of beverages while maintaining quality through vacuum preservation.

The invention [16] (Table 1, Position 5.2) is a vacuum-function tumbler designed to store food or beverages in an airtight environment, preserving freshness by preventing air contact. It features a sealed main body, dual cover system, a check valve, and a manual or electric pump to create a vacuum.

The patent [17] (Table 1, Position 6.2) presents a vacuum tumbler integrated with a mixer that allows food to be blended directly within a portable, vacuum-sealed container. The design enables easy transportation by allowing separation of the tumbler from the blending unit after processing. It prevents leakage even when the vacuum is released and improves hygiene by allowing all components, including the cover and valve, to be easily disassembled and cleaned.

The patent [18] (Table 1, Position 7.2) introduces a method and apparatus for rapidly marinating food by applying positive pressure to infuse marinating liquids deeply and efficiently. The result is a faster, more thorough marination process, enhancing flavor and tenderness in a significantly shorter time.

Solution [19] (Table 1, Position 8.2) introduces a novel magnetic stirring marinating device designed to address the shortcomings of traditional stewing equipment, such as uneven heating, complicated operation, cleaning difficulties, and energy inefficiency. The device integrates a magnetic stirring system, a spiral-shaped heating pipe, and a vacuum-insulated heating layer to ensure uniform heating and improved energy use. Its detachable stirring rotor enhances cleaning convenience, while the adjustable lid mechanism ensures safer operation.

The next patent [20] (Table 1, Position 9.2) relates to a vacuum boiling stew in soy sauce equipment designed to address issues in traditional marinating methods, such as salt corrosion, uneven floors, and microorganism control. The device includes a bucket shell with a dome and rotating mechanism, enabling efficient stirring and heating of marinated duck. The design improves automation, enhances hygiene, and facilitates the control of the marinating process, offering significant improvements over traditional methods.

The patent [21] (Table 1, Position 10.2) addresses the shortcomings of current food marinating storage methods, particularly the inadequate preservation conditions. The proposed storage device includes a vacuum environment that reduces oxygen levels, preventing spoilage and extending the shelf life of marinated products. The device features a storage box with a vacuum pump, refrigerator, and ultraviolet lamp for disinfection, ensuring the preservation of flavor, aroma, and appearance. Additionally, a rotating mechanism ensures uniform exposure to UV light and maintains temperature consistency, further preventing bacterial growth.

The patent [22] (Table 1, Position 11.2) introduces an apparatus and process for quickly marinating food, improving both flavor and tenderness. The device consists of a pressure-tight vessel and a pump system to remove air, reducing pressure inside. As the air is drawn out, the food swells and the air within it is removed, allowing the marinade to penetrate quickly. After a short period, the pressure is restored to atmospheric levels, enabling the marinade to fill the voids in the food, thus rapidly tenderizing and flavoring it.

The book [23] outlines key technological processes and machines used in the meat processing industry, especially aimed at ensuring even distribution of brine and producing high-quality items like sausages, canned, and semi-canned meat products.

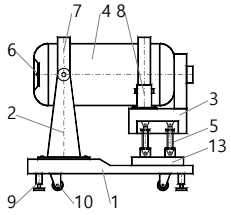
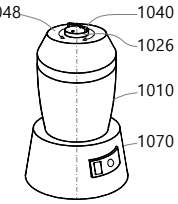
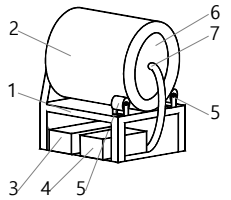
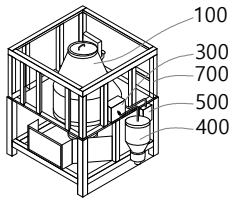
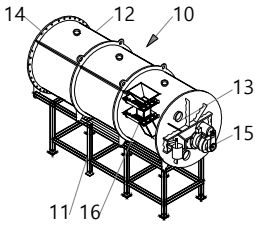
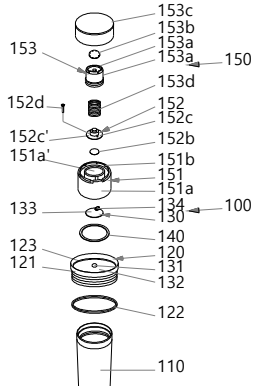
V. I. Ivashov [24] says that vacuum tumblers play a crucial role in the modern processes of meat marination and massaging . These machines operate in a vacuum-controlled environment, which removes air from the muscle tissues and facilitates deeper brine

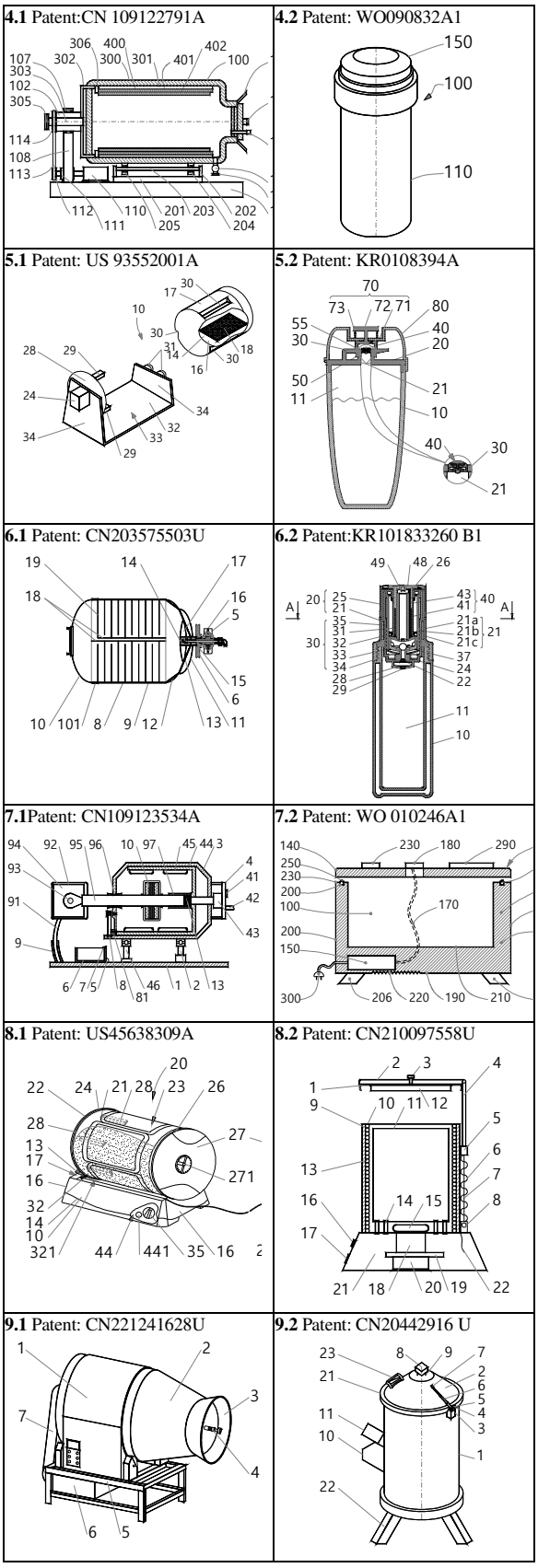
penetration, speeding up the maturation process. Through the slow and continuous rotation of the drum, ingredients are evenly distributed, protein structure is optimized, and the final product gains improved texture. Additionally, vacuum tumblers help increase yield and reduce losses by optimizing the technological process under hygienic and efficient conditions.

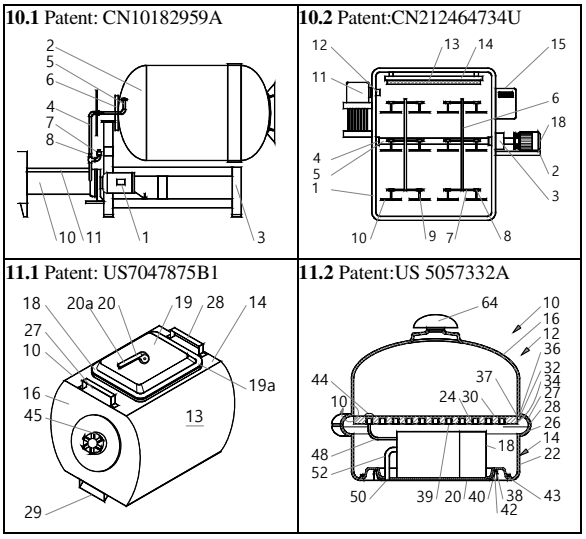
The sourse [25] says that vacuum tumblers are essential machines used in the industrial marination and massaging of meat. These devices operate in a controlled, airless environment, which prevents oxidation and allows for deeper penetration of the brine solution. Moreover, this process enhances muscle structure, increases product yield, and reduces losses during processing, making vacuum tumblers ideal for producing high-quality final products.

*Table 1*

**Idea matrix of various vacuum tumbler solutions .**

| Horizontal-axis tumbler | Vertical-axis tumbler |
|---|---|
| **1.1** Patent: CN106212621A  | **1.2** Patent: WO190537A1  |
| **2.1** Patent: CN202750621U  | **2.2** Patent:KR102593812B1  |
| **3.1** Patent: US0004346A1  | **3.2** Patent:KR0002991A  |






## 6. APPLYING AXIOMATIC DESIGN METHODOLOGY TO CONFIGURING A VACUUM TUMBLER MACHINE

Axiomatic Design (AD) is a design methodology developed by Professor Nam P. Suh at MIT in the 1980s. It provides a systematic framework to design products, processes, systems, or organizations with greater clarity, simplicity, and efficiency [26, 27].

At its core, Axiomatic Design is based on two powerful principles, called axioms, which guide designers toward the best possible solutions.

Independence Axiom: Maintain the independence of functional requirements (FRs). Each functional requirement should be satisfied without affecting others.

Independence axiom may be mathematical expressed by the design equation (1):

$$[FR] = [A]\,[DP] \quad (1)$$

Where:

*[FR]* is the functional requirements vector;

*[DP]* is the design parameter vector;

*[A]* is the design matrix

Information Axiom: Minimize the information content of the design. Choose the simplest, most robust design among alternatives. Designs that achieve goals with fewer variables or uncertainties are better.

Axiomatic Design uses four domains to break down the design process: Customer Domain (What is needed?), captures Customer Needs (CNs), which define user needs and expectations; Functional Domain (What should it do?), defines Functional Requirements (FRs) that must be met to satisfy the customer; Physical Domain (How will it be achieved?), specifies Design Parameters (DPs) that meet the functional requirements; Process Domain (How will it be produced?), defines Process Variables (PVs) to manufacture and implement the design.

Based on the research of existing solutions, summarized in the idea matrix in Table 1, by applying the mapping of the four domains presented above to a vacuum tumbler machine for marinating meat, we can define and align the domains as presented in Table 2. This structure helps ensure a traceable, rational design — from customer voice all the way to implementation — and helps prevent design coupling and inefficiencies.

*Table 2*

**Identifying the Four Domains of Axiomatic Design for a vacuum tumbler machine for marinating meat.**

| Domain | Description |
|---|---|
| Customer Domain (Customer Needs CNs) | CN1: Fast and deep marination with consistent flavor<br>CN2: Easy to operate with minimal training<br>CN3: Hygienic and easy to clean<br>CN4: Capable of handling various batch sizes<br>CN5: Reliable, durable, and safe to use |
| Functional Domain (Functional Requirements FRs) | FR1: Create and maintain a vacuum-sealed environment<br>FR2: Uniformly tumble meat to ensure even marinade absorption<br>FR3: Control marination time, speed, and vacuum parameters<br>FR4: Facilitate easy and hygienic loading, unloading, and cleaning |
| Physical Domain (Design Parameters DPs) | DP1: Integrated vacuum pump and chamber sealing system<br>DP2: Rotating drum with internal paddles and variable speed motor<br>DP3: Programmable control panel with sensors and timers<br>DP4: Stainless steel drum with CIP (Clean-in-Place) system and tilting mechanism |
| Proces Domain (Process Variables PVs) | PV1: CNC machining of stainless steel components for hygiene and durability<br>PV2: Assembly of vacuum system and drum rotation mechanisms<br>PV3: Software programming for control panel interfaces and cycle logic<br>PV4: Quality control procedures and compliance with food safety standards (e.g. HACCP, NSF) |

In Axiomatic Design, decomposition means breaking down Functional Requirements (FRs) into more detailed sub-requirements, and Design Parameters (DPs) into more specific sub-solutions while preserving the logic and independence between functions and solutions. It's not just a breakdown — it's a structured translation of goals into executable elements.

Table 3 presents the decomposition structure for functional requirements (FRs), and Table 4 presents the decomposition structure for design parameters (DPs).

The gain from decomposition is modularity (supports separation of concerns — one issue, one function, one solution), traceability (maintains logical link between what the system must do and how it will do it), Axiom 1 compliance (ensures functional independence is preserved throughout the system).

Figure 1 shows the Design Matrix for the proposed solution. The Design Matrix is a representation of the relationships between the Functional Requirements (FRs) and the Design Parameters (DPs). Design Matrix is one of the most essential tools in Axiomatic Design. It serves as the bridge between the Functional Requirements (FRs) and the Design Parameters (DPs) and allows the designer to evaluate the structure of the design.

| Functional Requirements (FMs) | Design Parameters (DPs) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **DP1** | DP1.1 | **DP2** | DP2.1 | DP2.2 | DP2.3 | **DP3** | DP3.1 | DP3.2 | DP3.3 | DP3.4 | **DP4** | DP4.1 | DP4.2 | DP4.3 | **DP5** | DP5.1 | DP5.2 | DP5.3 |
| | **FR1** | X | | | | | | | | | | | | | | | | | | |
| | FR1.1 | | X | | | | | | | | | | | | | | | | | |
| | **FR2** | | | X | | | | | | | | | | | | | | | | |
| | FR2.1 | | | | X | | | | | | | | | | | | | | | |
| | FR2.2 | | | | | X | | | | | | | | | | | | | | |
| | FR2.3 | | | | | | X | | | | | | | | | | | | | |
| | **FR3** | | | | | | | X | | | | | | | | | | | | |
| | FR3.1 | | | | | | | | X | | | | | | | | | | | |
| | FR3.2 | | | | | | | | | X | | | | | | | | | | |
| | FR3.3 | | | | | | | | | | X | | | | | | | | | |
| | FR3.4 | | | | | | | | | | | X | | | | | | | | |
| | **FR4** | | | | | | | | | | | | X | | | | | | | |
| | FR4.1 | | | | | | | | | | | | | X | | | | | | |
| | FR4.2 | | | | | | | | | | | | | | X | | | | | |
| | FR4.3 | | | | | | | | | | | | | | | X | | | | |
| | **FR5** | | | | | | | | | | | | | | | | X | | | |
| | FR5.1 | | | | | | | | | | | | | | | | | X | | |
| | FR5.2 | | | | | | | | | | | | | | | | | | X | |
| | FR5.3 | | | | | | | | | | | | | | | | | | | X |

**Fig. 1.** Design Matrix (FRs–DPs Mapping).

The structure of the design matrix classifies the Type of Design. The goal is to avoid coupling, which leads to design instability and unpredictability. If the matrix is coupled, the system must be redesigned or decomposed to eliminate dependencies.

*Table 3*

**Hierarchical Decomposition Structure for Functional Requremens (FRs).**

| Description of Functional Requiremens Structure |
|---|
| FR1: Create and maintain a vacuum-sealed environment |
| -FR1.1: Generate vacuum inside chamber; |
| FR2: Provide user-friendly marination controls |
| -FR2.1: Set vacuum and tumbling cycles easily; |
| -FR2.2: Display marination status in real time; |
| -FR2.3: Allow customization of marination programs; |
| FR3: Ensure safe, sanitary design and easy cleaning |
| -FR3.1: Use food-grade, easy-to-clean surfaces; |
| -FR3.2: Prevent meat clumping or damage during tumbling; |
| -FR3.3: Seal the chamber to prevent air leakage; |
| -FR3.4: Monitor and regulate vacuum pressure; |
| FR4: Enable flexible and uniform tumbling |
| -FR4.1: Rotate meat gently and consistently; |
| -FR4.2: Handle rotating chamber of different capacities; |
| -FR4.3: Handle different batch sizes effectively; |
| FR5: Build with robust and maintainable components |
| -FR5.1: Ensure long-term mechanical durability; |
| -FR5.2: Provide operator and system safety; |
| -FR5.3: Simplify repair and maintenance operations; |

*Table 4*

**Hierarchical Decomposition Structure for Design Parameters (DPs).**

| Description of Design Parameters Structure |
|---|
| DP1: Vacuum pump system with pressure control |
| -DP1.1: High-efficiency vacuum pump; |
| DP2: Programmable control panel with presets and digital display |
| -DP2.1: Human-machine interface (HMI); |
| -DP2.2: Real-time cycle indicators and status screens; |
| -DP2.3: Preset programs + manual override logic; |
| DP3: Stainless steel drum with internal paddles |
| -DP3.1: Polished stainless steel 304/316 drum; |
| -DP3.2: Internal paddles or baffles for mixing; |
| -DP3.3: Food-grade silicone gaskets and vacuum valves; |
| -DP3.4: Vacuum sensors and adjustable release valve; |
| DP4: Variable-speed rotating system for drum |
| -DP4.1: Variable-frequency drive motor (VFD); |
| -DP4.2: Adjustable slewing gear; |
| -DP4.3: Optimized drum geometry for different batch volumes; |
| DP5: Modular, durable mechanical and safety components |
| -DP5.1: High-durability bearings, seals, and stainless shafts; |
| -DP5.2: Safety interlocks, emergency stop system, motor protection; |
| -DP5.3: Modular assembly design for easy maintenance and upgrades; |

As can be seen in Figure 1, the Design Matrix considered for configuring a vacuum tumbler machine for marinating meat is diagonal, therefore uncoupled, each DP affects only one FR (satisfies Independence Axiom).

## 7. SOLUTION DESIGN

Considering the functional requirements and design parameters, as identified in the previous chapter, a vacuum tumbler machine for marinating meat was configured and built, as will be presented below in Figure 2, Figure 3, Figure 4.

A vacuum tumbler machine for marinating meat consists of a vacuum pump 1, a programmable control panel 2, a stainless steel drum with internal paddles 3 and a rotation assurance system for the drum 4. The programmable control panel provides the interface with the human operator and allows, through a potentiometer 5, the adjustment of the speed of the drive motor, a display 6 allows the programming of the processing time, and a tachometer 7 ensures confirmation of the actual achievement of the commanded speed.

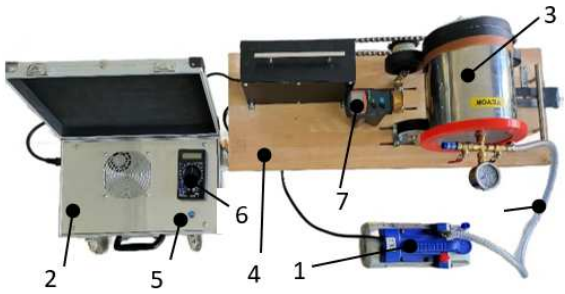



**Fig. 2.** Configuration of a vacuum trumbler machine

The stainless steel drum is made of stainless steel 304/316 and is equipped with internal paddles 8 to prevent meet clumping during tumbling. The stainless steel drum is fitted with a glass lid 9 which is placed on the drum by means of a silicone sealing ring 10. The vacuum is achieved by connecting the vacuum pump 1, through a hose 11. The valves 12 and 13 allow the pressure to be switched on/off, and the pressure gauge 14 allows the pressure to be controlled/displayed. After the working pressure, controlled by the pressure gauge 14, is reached, the hose 11 is disconnected from the drum. The process inside the drum can be monitored through the glass lid 9. The drums can be of different capacities.

Variable-speed rotating system for drum is made by mounting on a plate some rollers 15 and 16 which can be positioned by sliding along longitudinal channels a and b, the fixation being ensured by screws 17 and 18. The rollers 15 are provided with gear wheels 19 which can be driven into rotation by a chain 20 which is driven by another gear wheel 21 mounted on the shaft of a variable frequency drive motor 22.

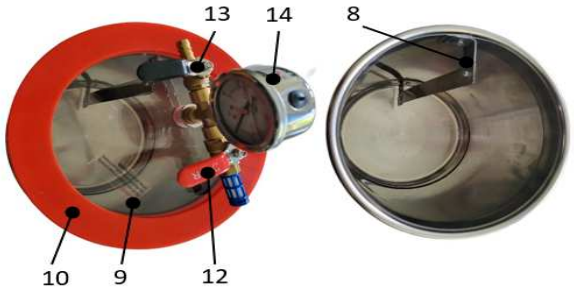



**Fig. 3.** Stainless steel drum with internal paddles

The positioning of the rollers 15 and 16 is done depending on the volume of the drum.

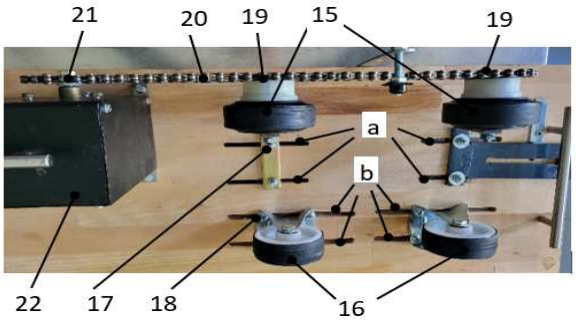



**Fig. 4.** Variable-speed rotating system for drum

Modular mechanical components (stainless steel bearings, seals and shafts, safety interlocks, motor shutdown and protection system) were used to ensure long-term mechanical durability, ensure operator and system safety, and simplify repair and maintenance operations.

## 8. CONCLUSION

The originality of the proposed solution is determined by its modular character. Obtaining the modular character of the solution was possible by applying the Axiomatic Design methodology. By systematically applying the

Axiomatic Design methodology, the new machine ensures that each functional requirement is independently satisfied without interference, leading to streamlined operations and reduced inefficiencies. The design incorporates advanced vacuum sensors and airtight components that maintain stable and adequate vacuum levels consistently, accelerating marinade penetration and reducing processing time. The use of modular components, such as easily replaceable paddles, sealing systems, and control modules, allows for quicker maintenance, easier customization, and reduced downtime, thereby increasing overall productivity. The inclusion of customizable rotation speeds and pressure settings enables flexible adaptation for different meat types and batch sizes, optimizing marination efficiency for various processing needs. These systematic improvements ensure higher consistency, faster processing times, easier maintenance, and better adaptation to different operational conditions, making the new vacuum tumbler efficient for research experiments.

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## Configurarea unei mașini de marinat cu vid pentru carne utilizând metodologia de proiectare axiomatică

Marinarea în vid este o tehnică avansată utilizată pentru a accelera absorbția marinadelor în carne, sporind aroma, frăgezimea și retenția umidității. Acest proces utilizează un mediu în vid pentru a forța marinada să pătrundă adânc în fibrele musculare, eliminând pungile de aer și deschizând structura cărnii. Un tambur cu vid este o mașină specializată concepută pentru a accelera procesul de marinare a cărnii, păsărilor de curte și fructelor de mare prin aplicarea presiunii vacuumului, în timp ce se rotește ușor produsul. Scopul lucrării este de a proiecta o mașină cu tambur cu vid care să asigure o marinare uniformă, eficientă și de înaltă calitate a cărnii într-un mediu controlat. Axiomatic Design (AD) oferă o abordare sistematică pentru proiectarea unei mașini cu tambur cu vid pentru marinarea cărnii, asigurând eficiență, performanță și ușurință în utilizare..

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