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Design and Development of Single-Handed Kitchenware for Individuals with Hand Disabilities

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ABSTRACT

Traditional kitchen equipment often poses significant challenges and risks for individuals with hand disabilities or impairments, increasing the likelihood of burns, cuts, and other injuries during food preparation. For people with physical disabilities or injuries affecting one hand, performing routine cooking tasks can be difficult and time-consuming. The reliance on traditional two-handed kitchen tools limits their ability to cook independently. This study aimed to design and develop innovative single-handed kitchenware equipped with multiple meal preparation tools and ergonomic features to enhance the cooking experience for individuals with hand disabilities. A combination of primary and secondary data was gathered through observations, interviews, and a review of journal articles. The research process involved concept development, three-dimensional modeling and analysis, and usability testing. The results demonstrated that the proposed single-handed kitchenware, made from PLA material, effectively integrates essential features such as a peeler, grater, cutting board, stopping rods, and a storage compartment into a single unit. While the design shows promise in improving meal preparation processes, achieving cutting and peeling speeds that are 51% and 65% faster, respectively, compared to conventional tools, further refinements are recommended. For instance, improvements in the grating function could optimize its overall performance and usability, particularly for individuals with hand impairments.

Keywords: Cooking, Design, Hand disability, Kitchenware, One hand, Single-handed.

1. INTRODUCTION

In a household kitchen, food preparation is a fundamental activity that involves tasks such as chopping vegetables, peeling fruits, and measuring ingredients, all of which are essential for creating balanced and flavourful meals [1, 2]. These tasks often require the use of sharp tools like knives and peelers, demanding precision and coordination to ensure safety. Once the ingredients are prepared, cooking begins, utilizing heat sources such as stovetops and ovens for techniques like frying, boiling, sauteing, and simmering [3]. Each method serves a specific purpose, such as enhancing flavors, altering textures, or achieving the desired consistency of a dish. The process also requires multitasking, such as stirring, seasoning, and monitoring, which can be challenging, especially when using traditional tools that often need both hands. This highlights the importance of designing kitchen tools that improve safety and efficiency for all users [4].

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Cooking tasks typically require the use of both hands, which can present significant challenges for individuals with limited dexterity or hand disabilities [5]. Conventional kitchen tools, such as knives, peelers, and graters, are often designed assuming that users have full mobility and the ability to use both hands simultaneously. For example, peeling an onion usually involves one hand holding the onion steady while the other operates the knife or peeler. While individuals with hand disabilities may still be able to perform such tasks, they often require more time and effort, leading to frustration or even safety risks [5]. Tasks like cutting, peeling, slicing, and grating become particularly difficult when only one hand is available, as these actions typically rely on the stability and control provided by the second hand. The design and functionality of traditional kitchenware often fail to accommodate these needs, highlighting the importance of developing more accessible and user-friendly alternatives to support individuals with disabilities in performing everyday cooking tasks efficiently and safely [6-8].

Several types of kitchenware have been developed to assist individuals who can only use one hand, offering innovative solutions to make food preparation safer and more efficient. For instance, kitchen scissors have been designed to replace a full set of knives and a cutting board, allowing users to cut, slice, and chop various ingredients without the need for multiple tools [9]. This versatile tool eliminates the need for traditional food choppers, vegetable slicers, and fruit cutters, streamlining the cooking process. Another innovative product is the handheld food chopper, which simplifies chopping, dicing, and cubing by simply closing the lid. This tool not only ensures uniform cuts but also reduces the mess typically associated with knives and cutting boards while preventing issues like teary eyes caused by onion vapors. Additionally, chopping boards with built-in containers or trays and an integrated grater have been introduced, allowing for organized food preparation and safe storage. More recently, specialized one-handed food preparation boards have been developed, enabling users to quickly chop, peel, and grate. These boards often include features like robust legs, suction cup feet for stability, and clamps to securely hold larger items such as bread or bowls in place during use. These innovations aim to enhance accessibility, safety, and convenience for individuals with limited mobility or dexterity [10].

Despite the advancements in one-handed kitchen tools, several limitations and drawbacks remain. For instance, kitchen scissors may not be suitable for cutting larger or harder items, such as thick vegetables or meat with bones, which limits their versatility. Similarly, while handheld food choppers ensure uniform cuts and reduce mess, they often require significant hand strength to operate, posing challenges for individuals with limited grip or reduced hand strength. Additionally, cleaning the intricate parts of such devices can be time-consuming and difficult. Chopping boards with built-in containers or trays and integrated graters provide organized food preparation and storage. However, they may lack the stability needed for heavy-duty tasks, especially if the suction cups or legs fail to hold firmly on uneven surfaces. More recently, one-handed food preparation boards, while innovative, can be bulky, taking up significant counter space, and their specialized design may not accommodate all types of food preparation tasks, such as slicing larger items or handling delicate ingredients. Furthermore, the cost of these specialized tools is often higher than traditional kitchenware, making them less accessible to some users. These drawbacks highlight the need for further improvements in the design, functionality, and affordability of single-handed kitchenware to meet better the needs of individuals with limited mobility or dexterity.

Given these limitations, it is clear that the design and development of new single-handed kitchenware should address the shortcomings of existing tools. The primary focus should be incorporating updated features and mechanisms to significantly enhance functionality, ensure user safety, and minimize potential risks. By addressing these challenges, the development of improved single-handed kitchenware could empower individuals with disabilities to perform cooking tasks more efficiently, safely, and independently.

2. MATERIAL AND METHODS

2.1 User Needs Determination

The determination of user needs is a crucial step before progressing to the design concepts of the kitchenware. To achieve this, two primary approaches were implemented: observation and survey. For the observation study, the session was conducted at a street food stall in Tambun Tulang, Arau, Perlis, operated by an individual with a hand disability. This setting was chosen to gain a deeper understanding of the characteristics and processes involved in food handling. The main business of the individual is selling burgers and other related menu items. Our findings revealed that the individual faced significant challenges in cooking and food preparation tasks, particularly during periods of high demand. He also reported experiencing a few minor accidents while working; however, the injuries were not severe due to certain precautions he had taken. Additionally, most kitchen tools used at the stall were poor, with some tools posing a risk of injury to the user. As a result, the individual had to exercise extra caution when using these tools, especially since he relied on only one hand. The individual also expressed feelings of fatigue and exhaustion when using the existing tools at his stall, as they lacked any assistive features. The common kitchen tools identified at the stall included knives, graters, peelers, containers, chopping boards, and several others. These tools, in their current state, were not optimized for one-handed use, further contributing to the challenges faced by the user.

To further validate the identification of user needs, several questionnaire surveys were conducted online. Eight respondents were selected, all regularly performing daily activities using only one hand. The survey included a series of questions related to the challenges being investigated, such as the frequency of cooking or meal preparation per day, the need for assistance during meal preparation, the time required to prepare meals, experiences with existing single-handed kitchenware, incidents of injuries while using conventional kitchen tools, difficulties in cutting, chopping, grating, and peeling, experiences in maintaining a clean workspace, and recommendations for improving the design of current kitchenware. The results revealed that seven out of the eight respondents cook more than twice a day. Among the participants, six prepare their meals independently, while the remaining two require assistance. Regarding the time taken to prepare meals, half of the respondents reported needing 30 to 40 minutes when using only one hand. A quarter of the participants required 20 to 30 minutes, while the remaining quarter needed only 10 to 20 minutes. In terms of experience with existing single-handed kitchenware, the majority of respondents indicated that they had not used such tools before. While cutting and chopping were reported as relatively manageable tasks when using one hand, grating, peeling, and maintaining a clean workspace were identified as significantly more challenging. The recommendations received include the development of a multifunctional kitchen tool that is easy to connect and use, capable of securely holding items for cutting and chopping tasks and functioning as an extra hand. Additional suggestions emphasize the need for a wide working area that directly transfers processed ingredients into a pan, along with features such as a built-in knife holder, a cutting surface with a secure holder, and an onion peeler. Furthermore, the tool should include an integrated chopping board, a knife holder, and an organized ingredient space.

2.2 Product Design Specifications

After analysing all the data collected from observations and questionnaire surveys, the proposed kitchenware design should meet the following specifications: 1) detachable body compartments or parts: the individual components of the kitchenware can be detached for easy storage and space-saving; 2) wide working area or chopping board: the platform provides a large surface area to support cutting and chopping activities; 3) rods as stoppers: these rods hold ingredients in place while cutting; 4) peeler with guiding walls: the peeler includes guiding walls to help users peel efficiently and easily; 5) interchangeable grater: the grater can be replaced with different sizes for various grating needs; 6) lightweight plastic materials: using lightweight plastics for the main body parts prevents handling difficulties; 7) manual operating system: a manual system reduces the overall weight of the kitchenware; 8) adequate overall dimensions: the size is suitable for one-handed operation, being neither too large nor too small.

The criteria were subsequently applied in a functional analysis using a morphological chart. This chart outlined various functions aligned with the product specifications, which were expanded upon during a brainstorming session. As a result, seven functional groups were developed for the proposed design: total mass, main dimensions, thickness of the main parts, grater angle, chopper design, stopper design, and peeler design. Each function was expanded into at least four detailed ideas to generate a variety of possible solutions. Various combinations of these ideas were used to create four different design concepts. Figure 1 illustrates these four design concepts of the kitchenware in sketch form.

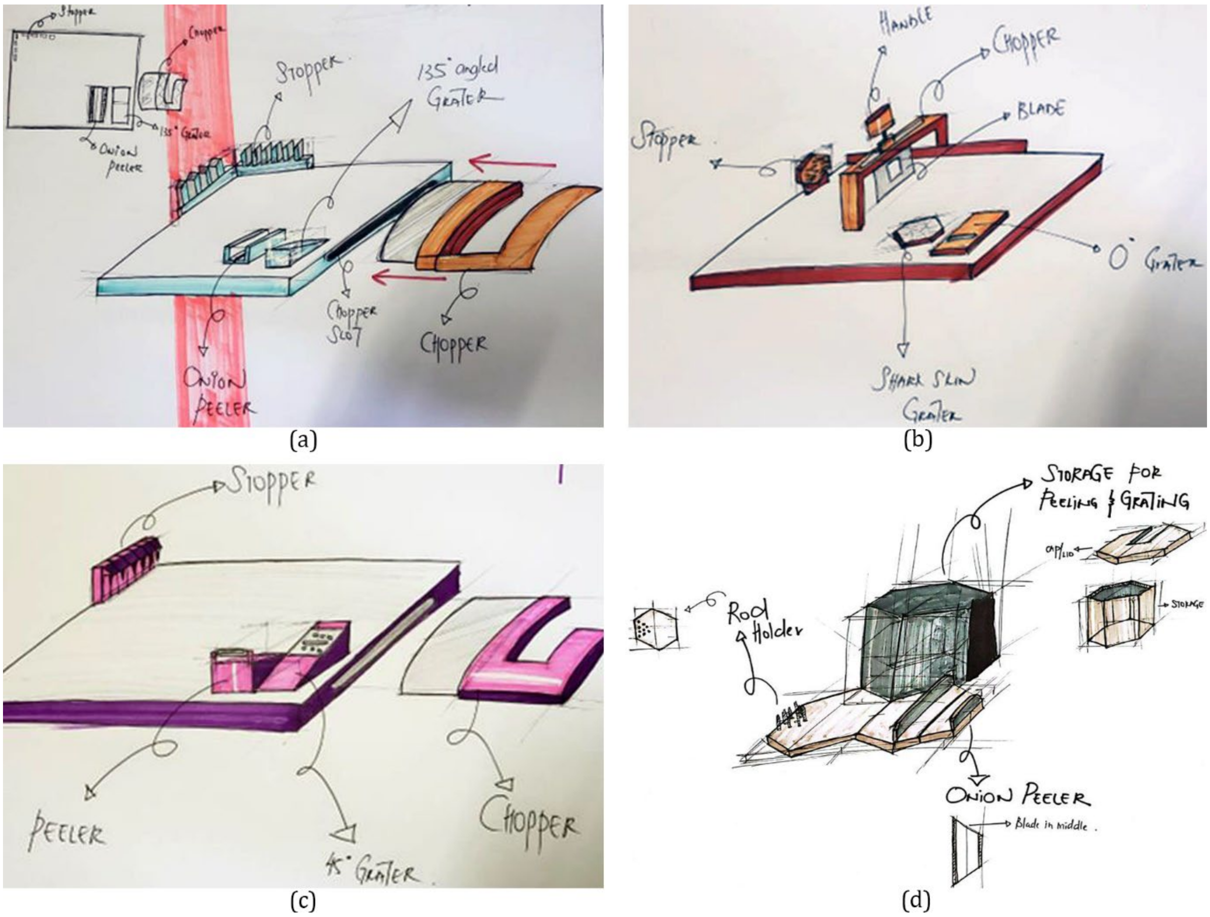


Figure 1: Four different design concepts of the proposed single-handed kitchenware: (a) Concept A, (b) Concept B, (c) Concept C, and (d) Concept D.

Concept A consists of five components: a stopper, an onion peeler, a grater, and a chopper. The stopper is designed as a spike at the edge of the chopping board, securing ingredients like tomatoes, onions, and eggplants for chopping, eliminating the need to hold them with one hand. The chopper is integrated into the board and features a slightly curved blade at the end, allowing for chopping without a slicing motion that might displace the ingredients. The onion peeler is shaped like a case with a central blade, enabling users to peel onions by rolling them through the path, creating small slices across the onion skin. The grater is angled at 135 degrees for ergonomic use. Concept B features a hexagonal base stopper with multiple spikes to hold ingredients securely. The chopper includes a double-sided blade, allowing the handle to move back and forth for faster slicing. The grater, inspired by the wasabi grater, has a shark skin texture and can also peel hard-skinned ingredients like galangal, turmeric, and ginger. Concept C includes an adjustable claw-like stopper that can be raised or lowered based on the size of the ingredient. It also features a standard peeler for items like carrots and potatoes, as both peelers and graters typically require two hands for stability. Additionally, a slotted chopper is included in this design. Concept D is more modern, using a hexagonal shape as its foundation. It consists of three parts, each with hexagons connected using modular techniques. The first part serves as a chopping board with an attached rod to hold ingredients. The second part is for grating and standard peeling, with built-in storage. The third part is designed for onion peeling, featuring a centrally attached blade.

The proposed design concepts were thoroughly evaluated based on the finalized user needs. A comparison of the concepts was conducted using several selection criteria to identify the most suitable option, employing both concept screening and concept scoring methods. A selection matrix was developed using the identified user needs during the concept screening process. Additionally, an existing product was chosen as a benchmark for comparison. Each concept was assessed against the selection criteria using the symbols "+," "−," and "0", which represented performance that was better, worse, or equal to the benchmark product, respectively. The ranking of the design concepts was then determined by calculating the net score, which was the sum of the "+" symbols. The concept with the highest net score was ranked first, while the one with the lowest score was ranked last. Furthermore, an additional evaluation was conducted for all concepts to identify areas requiring revision. Table 1 presents the evaluation data from the concept screening process for all proposed product concepts. The results indicated that concepts A, B, and C were eliminated from further consideration.

Table 1: Concept screening of all design concepts.

No.	Selection Criteria	Concept A	Concept B	Concept C	Concept D	Competitor (Reference)
1	Chopping board design	+	+	0	+	0
2	Chopper design	+	+	0	0	0
3	Wide working area	0	-	0	0	0
4	Adjustable mechanism	-	0	0	0	0
5	Portable design	+	+	0	+	0
6	Peeler design	+	+	0	+	0
7	Grater design	-	-	-	+	
	Sum 0's	1	1	6	3	6
	Sum –'s	2	2	1	0	1
	Sum +'s	4	4	0	4	0
	Net Score	2	2	-1	4	0
	Rank	2	2	4	1	3
	Continue?	No	No	No	Yes	No

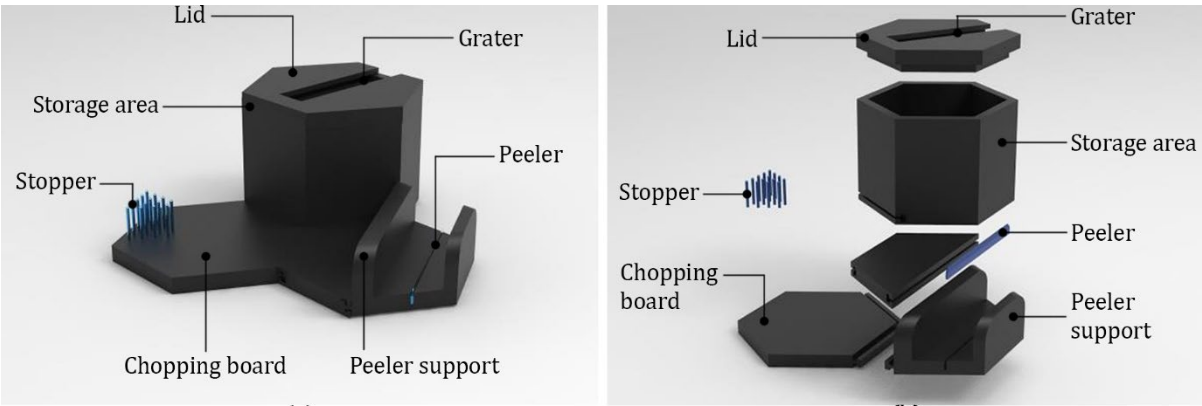
Concept D was then thoroughly evaluated during the concept scoring stage to confirm its superiority over the existing design. A rating scale was applied to each selection criterion to reflect its level of importance or significance. The scale ranged from 1 to 5, where 1 represented "Poor," 2 "Ok," 3 "Fair," 4 "Good," and 5 "Excellent". Besides, each selection criterion was assigned a weightage percentage (%) based on its relative contribution to the product's functionality. Table 2 illustrates the concept scoring process conducted for both Concept D and the existing product. Concept D achieved the highest total score, surpassing the existing design, and was therefore selected as the final design for further development. Minor modifications were also made to Concept D to enhance certain features.

Table 2: Concept scoring data for Concept D and existing product.

No.	Parameter		Concept D		Existing Product	
	Selection Criteria	Weightage (%)	Rating	Weightage Scoring	Rating	Weightage Scoring
1	Chopping board design	10	4	0.4	3	0.3
2	Chopper design	20	4	0.8	2	0.4
3	Wide working area	10	4	0.4	3	0.3
4	Adjustable mechanism	10	1	0.1	1	0.1
5	Portable design	20	3	0.6	3	0.6
6	Peeler design	20	4	0.8	1	0.2
7	Grater design	10	4	0.4	1	0.1
	Total Score		3.5		2.0	
	Rank		1		2	
	Develop?		Yes		No	

2.3 Three-Dimensional Modelling and Prototype Development

The finalized design was thoroughly modeled in three dimensions (3D) using the CATIA computer-aided design (CAD) software. Various features within the software, including revolve, extrude, extruded cut, mirror, and shell, were employed to create the individual components of the model. After completing the design of each part, they were assembled to construct the final 3D representation. To ensure the proposed design adhered to ergonomic standards, the general dimensions of kitchenware were referenced from data available in the literature. Figure 2 presents the 3D model of the kitchenware design, shown in both fully assembled and exploded view configurations.

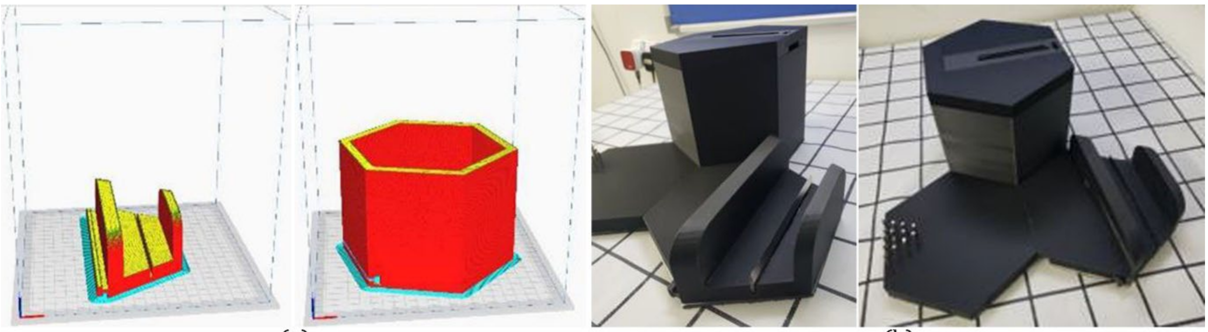


(a) (b)

Figure 2: (a) The isometric view of the 3D kitchenware model and (b) The exploded view of the 3D kitchenware model.

The proposed design is primarily divided into four main sections: the cutting or chopping area, the peeling area, the grating area, and the storage area. The design features five primary boards that can be easily detached and reassembled. The cutting area is equipped with several stopper rods securely fixed to the board, ensuring the ingredients remain stable during use. The design includes support or guidance features for the peeling section to prevent ingredients from slipping out of the peeler during use. Several smaller boards are assembled to form a container section for storing dry ingredients such as onions, garlic, and similar items. Besides, this storage area can also serve as a space to hold grated ingredients. The grater is positioned on top of the storage container and features a replaceable cutter for added convenience. The overall height of the kitchenware is designed to be ergonomically appropriate, ensuring ease of use. The kitchenware is designed for safety and without sharp edges or hazardous parts. The main body is constructed from polylactic acid (PLA) using 3D printing, while all cutters are made from stainless steel. The use of lightweight PLA material for the main body makes the kitchenware easy to carry and store. The proposed kitchenware model has dimensions of 303 mm in width, 300 mm in length, and 121 mm in height.

The 3D model files were exported in the required format using CATIA software and thoroughly reviewed prior to creating a mock-up of the product for preliminary functional testing. Following this, the process advanced to prototype fabrication, which incorporated both metalworking and 3D printing methods. Figure 3 provides an overview of the fabrication steps as well as the finalised prototype.



(a) (b)

Figure 3: (a) The 3D printing processes. (b) Finished prototype of single-handed kitchenware.

2.4 Structural Analysis and Functional Testing

To evaluate the structural strength of the proposed kitchenware, a 3D linear static finite element analysis (FEA) was performed. Since the primary purpose of the design is to support various meal preparation tasks, two distinct loading scenarios – vertical and horizontal loads – were analyzed during the computational structural assessment (Figure 4). FEA is a widely recognized numerical method commonly used to address mathematical modeling problems in science and technology. The kitchenware design's geometric models were transferred to the ANSYS FEA software in IGS file format (.igs). The material properties applied to the models were considered isotropic, homogeneous, and linearly elastic. The elastic modulus (E) and Poisson's ratio (v) values used in the analysis are listed in Table 3.

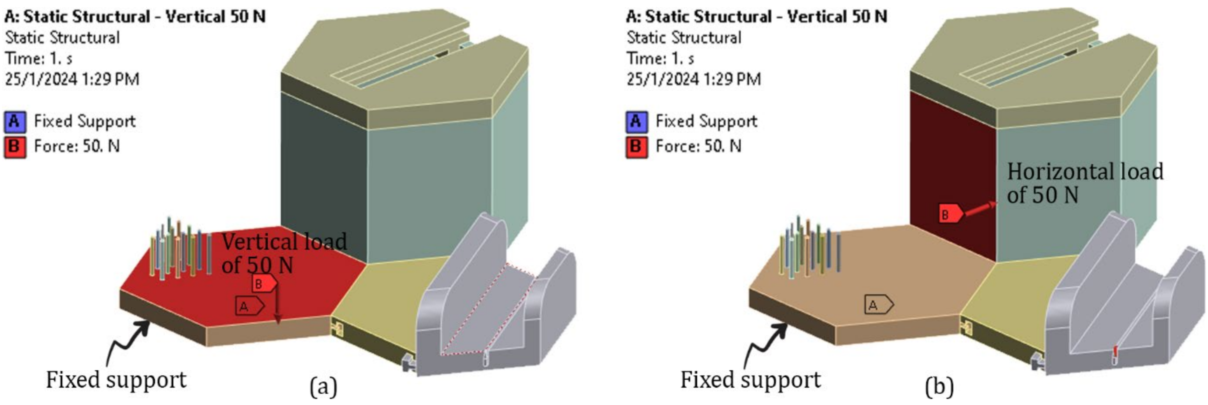


Figure 4: The location (red area) of two different forces applied on the model, (a) vertical load and (b) horizontal load and fixed support.

For the loading conditions, vertical and horizontal forces of 50 N were applied separately to the flat surface of the chopping board and the vertical surface of the storage area, respectively (Figure 4). These forces represent the typical hand pressure exerted during meal preparation tasks. Regarding the boundary conditions, all bottom surfaces of the chopping board in contact with the ground were fully constrained, restricting both translational and rotational movement in all directions. A four-node solid tetrahedral element was selected as the mesh type and applied to all parts of the model. To ensure the accuracy and consistency of the mesh, a uniform mesh size was used across all components, particularly in critical areas. All contact surfaces within the assembly model were assumed to be perfectly bonded, ensuring strong connections between the components. The meshing process was carried out using the software's automatic meshing tool, resulting in a total of 37,510 nodes and 18,722 elements. The structural response to the applied loads was analyzed in terms of maximum equivalent von Mises stress (MPa), maximum deformation (mm), and the safety factor.

Table 3: Material properties used in the analysis.

Material	Elastic Modulus (GPa)	Poisson's Ratio	Yield Strength (MPa)	References
PLA	4.107	0.30	26.082	Dharmalingam et al. (2022) [11]
Stainless steel	200	0.30	250	Ashby (2013) [12]

The completed prototype was tested to assess its usability and functionality in preparing cooking ingredients through three specific activities: cutting/chopping, peeling, and grating. The usability testing was conducted at a food stall operated by an individual with a hand disability. To evaluate the prototype's performance, a comparison was made with the same individual performing identical tasks using traditional meal preparation tools. The evaluation primarily focused on the time required to complete each activity – cutting/chopping, peeling, and grating – using the proposed prototype versus conventional kitchen tools.

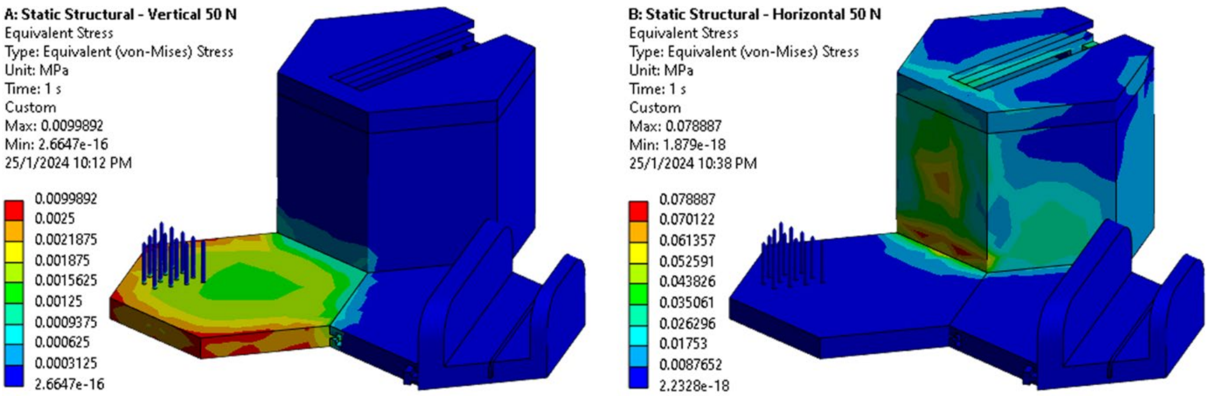
3. RESULTS AND DISCUSSION

3.1 Structural Analysis Results

The results of the 3D linear static finite element analysis (FEA) were presented in terms of the maximum magnitude and distribution of equivalent von Mises stress, total deformation, and the safety factor. Stress and deformation distributions within the models were visualized using color contour plots, where the most critical regions were highlighted in red and the least critical regions in blue. FEA is a widely recognized numerical method commonly employed to address problems associated with mathematical modeling in the fields of science and technology [13-20].

Under vertical loading applied to the board, the analysis revealed that the maximum stress, measuring 0.00999 MPa, occurred at the base of the stopper rod, as illustrated in Figure 5a. Overall, the structure exhibited adequate capacity to withstand the applied vertical load, with a minimal risk of failure under normal operating conditions, as the maximum stress value was significantly lower than the yield strength of PLA (26.082 MPa). For horizontal loading applied to the storage body, the results indicated that the maximum stress, reaching 0.07889 MPa, was concentrated at the bottom of the storage body, as shown in Figure 5b. These findings suggest that the structure could adequately support the horizontal load with a similarly low risk of failure. However, comparing the two loading conditions revealed that horizontal loading (0.07889 MPa) induced a significantly higher maximum stress than vertical loading (0.00999 MPa), with a percentage difference of approximately 155%.

Under vertical loading, the regions surrounding the storage compartment and the peeler section experienced minimal stress levels. The higher stress observed in the chopping board area compared to other regions can be attributed to the increased bending resistance of the structure in response to the applied load. In contrast, the configuration of the chopping area under horizontal loading exhibited greater stability and rigidity, resulting in more stress being concentrated in the storage compartment rather than in other regions. Regardless of the loading condition, the calculated Factor of Safety (FOS) for the kitchenware structure was consistently high, exceeding a value of 15 (>15), as depicted in Figures 6a (vertical load) and 6b (horizontal load). The FOS values were significantly high due to the low maximum stress levels recorded, which were only 0.00999 MPa under vertical loading and 0.07889 MPa under horizontal loading. These results indicate a minimal likelihood of structural failure.



Maximum stress = 0.00999 MPa
(a)

Maximum stress = 0.07889 MPa
(b)

Figure 5: The critical stress regions in the single-handed kitchenware model under the application of (a) vertical and (b) horizontal loads.

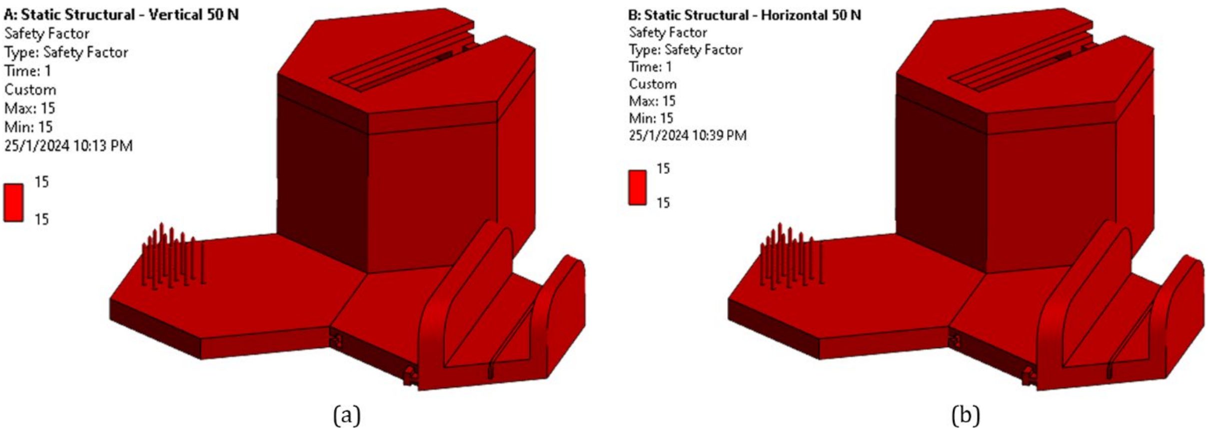


Figure 6: The safety factor plots of the single-handed kitchenware model under the application of (a) vertical and (b) horizontal loads.

The total deformation analysis revealed that the horizontal load resulted in a maximum displacement of 268.34×10^{-5} mm, which was significantly higher than the displacement caused by the vertical load (1.2637×10^{-5} mm), with a percentage difference of approximately 198.1%. Under vertical loading, the maximum deformation occurred at the edge of the board, as shown in Figure 7a. In contrast, for horizontal loading, the maximum deformation was concentrated in the central region of the storage body, as illustrated in Figure 7b. The increased deformation in the middle section of the storage compartment can be attributed to the higher bending stress induced by the horizontal load. To minimise the risk of significant deformation that could lead to structural failure, users are advised to manage the lateral load applied to the storage section carefully. As the applied force increases, the likelihood of deformation also rises.

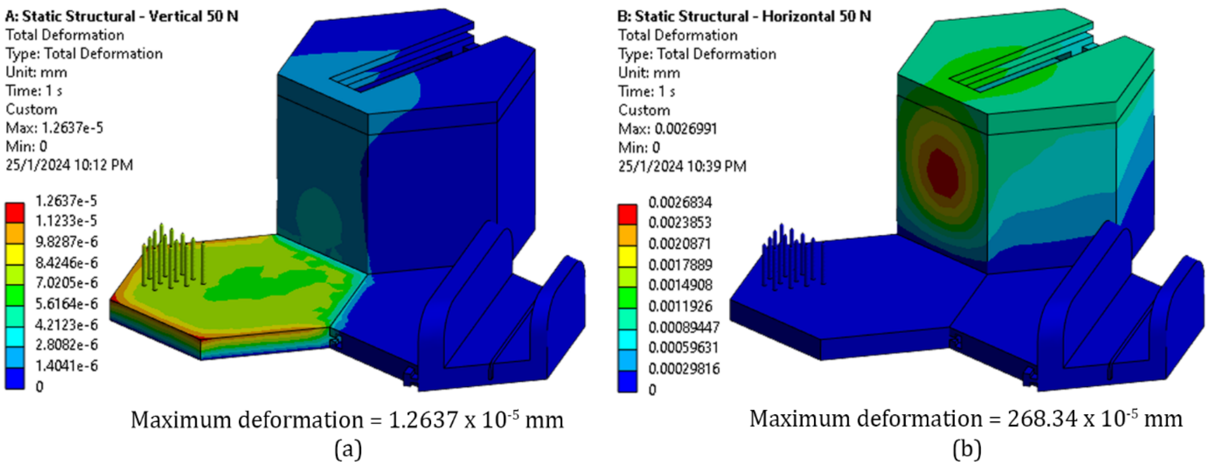


Figure 7: The critical deformation region of the single-handed kitchenware model under the application of (a) vertical and (b) horizontal loads.

3.2 Prototype Functional Testing Results

Before conducting usability testing, it is essential for the user to be familiar with the operation of the kitchenware. The process begins with placing the kitchenware on a stable, flat surface. Once all the components are prepared and available, the user must assemble the individual parts to form a complete and functional unit. After assembly, it is crucial to ensure that the primary working surfaces of the kitchenware, such as the chopping board, are clean and ready for use.

Following this, the user can proceed with meal preparation activities, including cutting, peeling, and grating. During these tasks, the user must exercise caution and prioritize safety, particularly because the kitchenware is designed for single-handed operation. Improper handling or neglecting safety precautions may lead to accidents, such as cuts, injuries, or kitchenware falling to the floor. Therefore, users are advised to handle the tools carefully to minimize risks.

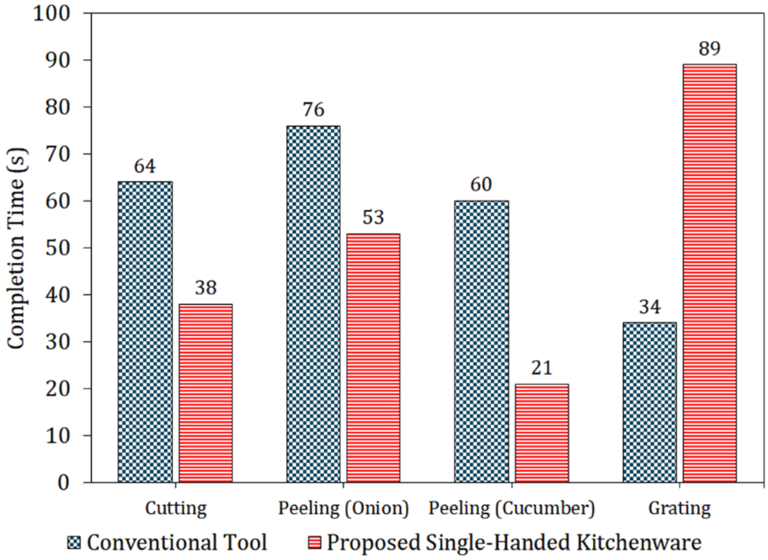


Figure 8: Comparison of different meal preparation activities between the conventional tool and proposed single-handed kitchenware.

Figure 8 illustrates the time taken (in seconds) to complete various meal preparation tasks during usability testing, comparing conventional tools with the proposed single-handed kitchenware. The study focused on three key activities: cutting (Figure 9), peeling, and grating. The results demonstrated a significant reduction in the time required for meal preparation tasks when using the proposed kitchenware, particularly for individuals with single-handed functionality, compared to conventional tools.

For the cutting activity, the proposed kitchenware reduced the time required to 38 seconds, compared to 64 seconds when using a conventional knife, representing about a 51% reduction in time. Similarly, for peeling tasks, the single-handed kitchenware showed notable improvements. Onion peeling was completed in 53 seconds, and cucumber peeling was done in 21 seconds, compared to 76 seconds and 60 seconds, respectively, with traditional peelers. These results indicate a time reduction of approximately 30.3% for onion peeling and 65% for cucumber peeling.

Cutting the cucumber using a knife (conventional tool).
(a)

Cutting the cucumber using the proposed kitchenware.
(b)

Figure 9: Comparison of cutting a cucumber using a knife (conventional tool) and the proposed single-handed kitchenware.

However, the grating process did not meet the expected performance improvements. The proposed kitchenware required 89 seconds to complete the grating task, compared to only 34 seconds with a conventional grater, representing an 89.4% increase in time. This underperformance can be attributed to two primary factors. First, the bottom surface of the kitchenware lacked sufficient grip, causing instability during the grating process, which requires significant downward force. Second, the blade used for grating was too thin and prone to bending under pressure, further reducing efficiency.

The usability testing identified several potential issues that could affect the performance and safety of the proposed kitchenware. One critical concern is the presence of sharp edges on the corners of the kitchenware body, which pose a safety risk to users. To address this, it is recommended to smoothen the edges or apply protective layers to cover the sharp areas. Another issue is the insufficient grip of the kitchenware on the working surface, which can cause slipping during use. To resolve this, incorporating high-quality rubber materials on the base is suggested to enhance stability and prevent movement. Additionally, the attachment of the board panels was observed to be suboptimal, with some parts failing to fit securely, leading to a loose assembly. Improving the attachment mechanism and ensuring tighter tolerances in the design would enhance the overall structural stability and rigidity of the kitchenware.

The usability testing results highlight the potential of the proposed single-handed kitchenware to significantly improve meal preparation efficiency for individuals with limited hand functionality. While the cutting and peeling tasks demonstrated substantial time savings compared to conventional tools, the grating process requires further refinement to meet performance expectations. Addressing the identified issues, such as safety concerns, surface grip, and assembly stability, will enhance the usability and reliability of the kitchenware, making it a more effective solution for single-handed users.

4. CONCLUSION

The findings from the design development process, computational structural analysis, and usability testing indicate that the proposed single-handed kitchenware design demonstrates satisfactory performance and functionality. The results of the structural analysis revealed that the mechanical stress and total deformation experienced by the design were within acceptable limits, ensuring the kitchenware's ability to withstand the applied loads during use. This confirms the structural integrity and durability of the proposed design under typical operating conditions.

Furthermore, the improved working mechanism of the kitchenware, which emphasizes handling efficiency for various ingredient preparation activities, incorporates essential safety features and ergonomic considerations. These enhancements not only improve the overall user experience but also significantly reduce the likelihood of unfavorable incidents, such as accidents or operational inefficiencies, during single-handed use. By addressing these critical aspects, the design effectively mitigates the limitations commonly associated with conventional kitchenware.

In conclusion, the newly developed single-handed kitchenware design successfully overcomes the drawbacks of existing tools, offering a safer, more ergonomic, and more efficient solution for individuals with limited hand functionality. This innovative approach can potentially improve accessibility and usability in kitchen environments, making it a valuable contribution to assistive kitchenware design.

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