International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Techno-Package for Innovated Fuel-Efficient Oven

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Abstract: ***This study was a charcoal oven innovation.The research was conducted in Poblacion, Danao City, Cebu. Its aims were to produce a fuel-efficient, ergonomically sound, and portable oven suitable for the needs of mobile bakers, specifically rice cake vendors; it examined the acceptability of the innovated fuel-efficient oven. There were two (2) respondent groups involved in this study: the 10 bakers and 10 experts. It used the descriptive method of research. The questionnaire was divided into two (2) parts; the first part was rated only by the experts because it delved into the acceptability of the technical requirements in the design, tools, equipment, and materials needed, ergonomics, and safety. The result concluded that all of the design requirements were met. In the second part of the questionnaire, both the bakers and experts evaluated the acceptability of the oven as to its relative advantage, compatibility, simplicity, trialability, and observability. The average weighted mean for the bakers was 4.84-highly acceptable, whereas for the experts it was 4.75-highly acceptable. The responses of the two (2) groups were compared using a t-test. The result revealed that the .23 computed p-value was greater than the alpha level of 0.05. Therefore, both bakers and experts had similar perceptions of its acceptability. It was concluded that the innovative, fuel-efficient oven was adaptable to both bakers and experts. It is thereby recommended that the innovative fuel-efficient oven be adopted.***

Keywords: Technology management; innovated fuel-efficient oven; descriptive method; Cebu, Philippines

1. Introduction

Baking is a means of cooking food in dry heat [1]. The purpose is to produce food with a distinctive odor, flavor, color, and texture. It is another way of preserving food, aside from cooking.

This process of preserving food is very ancient. In fact, there is much evidence that proves that it existed during the Stone Age. Archeologists unearthed jumbo ovens in Central Europe and Japan that were used for baking elephant meat[2]; another is in Croatia, a 6,500-year-old multipurpose oven with uses not only limited to baking food but also for boiling water and central heating for homes[3]

This knowledge has been handed down to every generation. It is old as human civilization itself. There are a lot of innovations concerning the design of the oven, including its introduction to different kinds of fuel it uses, such as wood, charcoal, kerosene, LPG, and electricity. Most of these ovens use liquefied petroleum gas (LPG) as fuel.

In the Philippines, the consumption of LPG in households is higher than that of kerosene [4]. However, it has the drawback of being unstable due to external causes like production controls, wars, recessions, and natural disasters, which are primarily responsible for oil price fluctuations [5]. Relying on one source of energy is not a good proposition. It is vital to find an alternative-charcoal is the ideal one. It is a renewable source of energy.

Based on the survey conducted by the National Statistics Office, households switched from LPG to charcoal owing to its high cost (National Statistics-Energy Consumption, 08/31/2005). It is readily available in the market because of its high demand. The accounted consumption in the commercial sector in Cebu City is 49%, and this is composed of restaurants, bakeries, barbecue, and lechon vendors. It is also preferred by low-income households to either be their principal or secondary energy source [6]. It is a major alternative to imported energy. Furthermore, charcoal trading is the source of income for many rural and urban households [7].

Most households in developing countries are still using biomass for their energy needs for cooking. The demand for stoves and ovens that burn fuel efficiently following the principles of complete combustion is the solution to prevent household air pollution [8].

The goal of this research was to provide an affordable and efficient oven that could use a fuel readily available in the locality. This innovative, fuel-efficient oven could bake almost anything, but it had some limitations due to the size of its oven cavity. Its height became shorter by just 5.5 centimeters, which was ideal only for small bread and cakes. The main reason was that it focused on the baking process of rice cake. The heat must be close to the batter by providing heat on top and bottom, considering how rice cake was baked. Its capabilities were similar to those of other ovens, which used radiation, conduction, and convection—the three (3) fundamental means of heat transfer.

There are four (4) categories of innovation: incremental, radical, modular, and architectural [9]. This research was based on incremental innovation. It concentrated solely on modifying an existing idea or product, which is the oven. The modifications applied were the inclusion of drawers for the ash and fuel trays, and improved fuel efficiency by applying the principles of complete combustion and heat retention over the existing ones used by the rice cake bakers/vendors.

This phenomenon is attributed to the “Diffusion of Innovation Theory” by Everett M. Rogers in 1962. It is one of the social science theories. Since then, it has been used as a theoretical framework in various fields, with over 508 diffusion studies in 40 years and still counting. In recent years, technology has been rapidly evolving; the theory has

become widely used in the technology field. He used the words "innovation" and "technology" synonymously. He theorized that innovation must possess five (5) qualities for it to be adopted by the masses. These are the relative advantages of compatibility, complexity/simplicity, trialability, and observability [10].

Adopters are not easily persuaded by just the proper dissemination of ideas or the introduction of products. Some factors influence their adoption of the innovation. These are the evident results, personally perceived and experienced by them. Because of this, the design had a relative advantage or was superior to the existing ones in heat retention, low fuel consumption, and less smoke emission. It was compatible with the socio-economic status, expectations, and needs of the adopters, who were mobile bakers. It was compact and portable to accommodate their needs. In this way, it was advantageous for them to transport all their goods at once. Moreover, it was able to bake efficiently.

Regarding rice cake production, it is usually a small-scale industry run by a single person or group of family members. The problem faced by these entrepreneurs is the lack of adequate capital to buy modern equipment and expand the business. Providing them with an affordable oven that is easy to fabricate would help them a lot. The innovative, fuel-efficient oven would give them the opportunity to own one that suits their baking situations. By attending to their needs, they can bake comfortably. It was purposefully made to be compact so that portability was feasible; it was perfect for small-scale or traveling bakers.

Rice cake is almost present in countries with rice as the staple food. It is prepared differently in every culture. For us Filipinos, it is one of our famous delicacies.

A charcoal oven for baking rice cakes is rarely seen; hence, most bakers are still using the conventional clay pot with fire on its top and bottom with coconut husk as fuel. The traditional mode of baking by using clay pots is still widely used today by vendors throughout the Cebu province.

Its design flaw is its inability to retain heat much longer because the fuel is not enclosed in a chamber. Having an oven that burns fuel well but does not retain heat is not considered fuel efficient. More fuel is needed because the heat is wasted.

Pouring rice cake batter in an individual clay pot is time-consuming, so production is delayed. A big baking area is also needed to accommodate all of them because space must be provided between them for enough leeway.

Batch baking is possible by using an oven. It has advantages over the clay pot in many ways. The baker can concentrate on one task at a time. The pouring of batter into the molders can be done easily on a tray. After putting the tray in the oven, the next thing he does is maintain the oven's temperature and refuel it when needed.

The heat in the clay pot is not confined to a chamber, unlike in an oven, so the baking time is extended. It cannot be easily transported because it is bulky and fragile. It takes considerable time for the baker/vendor to set up a number of them. Usually, the fuel used is coconut husk, which emits thick smoke and poses a serious health problem. There are many improvised charcoal ovens for baking rice cakes, but they lack the characteristics inherent to an efficient oven, especially in ergonomics and heat retention.

The intention of integrating the process of baking rice cake into the design was to alleviate the baking situation of the marginalized street bakers and vendors. Furthermore, it perpetuated the long tradition of baking the Filipino delicacy.

An oven is said to be fuel efficient if it consumes less fuel and minimizes heat loss. Heat loss is unavoidable, but it can be reduced by determining the problems related to the heat processing equipment itself [11]. It can be implicated in different areas, from its heat storage, outside walls, to trays or openings where heat escapes. Too much air cools the combustion chamber, and it can also dispel heat rapidly. Nitrogen gas comprises almost 80% of air and does not contribute to combustion; rather, it adds to the weight of gas that absorbs heat energy. It is the basis for why air intake should also be controlled [12].

The trend of an increasing demand for biomass as fuel does not letting up because of population growth. The International Energy Agency stated that last 2015 the demand increased to 2.6 billion and by 2030 it will go up 2.7 billion. Research on clean cooking stoves and ovens in Sub-Saharan African countries is progressing. In the International Energy Agency (IEA) survey in 2004 countries of these regions topped in biomass consumption with 76 percent of the total population [13]. They have been developing fuel-efficient cooking and baking appliances that use biomass. The aim is to curb the problems of indoor pollution and forest degradation.

According to the World Health Organization (WHO), 4 million people die every year due to household air pollution from cooking with solid fuel. The most affected are women (who always do the cooking) and children, who spend most of their time at home. This is an alarming scenario; more and more women and children will die if this continues to occur every year. The problem caught the attention of former U.S. Secretary of State, Hilary Clinton, and launched the "Global Alliance for Clean Cookstoves" in 2010, a consortium of both private and public sectors supervised by the United Nations [14]. Its aim is to protect the environment and conduct research on producing affordable, efficient, and clean cookstoves for the masses.

Charcoal is one of the biomass fuels. It is efficient and has a higher heating value with around 7500 Kcal/kg compared to green wood with around 3500 Kcal/kg or dried wood with 4500 to 4770 Kcal/kg. As to the heating value of the coconut husk, it is almost like wood of about 4000 Kcal/kg [15]. Another aspect that charcoal has an advantage over fuel wood is its higher energy yield of about 28 percent compared to wood with just an average of eight (8) percent [28]. To exploit its full potential, it should be complemented with an oven that burns fuel efficiently.

Charcoal is more efficient when it is hot. In this way, it is necessary to maintain the feeding of its fire when baking to take advantage of its heat. It has the highest firepower (release of energy during burning in a unit of time) among kerosene, wood, and electric stoves. It has the lowest cost of thermal energy, with savings of up to 74.52% in controlled cooking [16]. Another comparative study conducted by [17]. on the utilization of charcoal, sawdust, and rice husk revealed that charcoal has the highest combustion properties, exhibiting a 2.4 kJ. of energy per hour. It is suitable for baking and roasting.

Incomplete combustion in charcoal usually occurs during lighting or ignition. This is the time that someone near it is exposed to harmful emissions. Designing an oven that burns fuel efficiently produces dual results. Firstly, it reduces air pollution and decreases the user's exposure to it secondly; it consumes less fuel, thereby translating into [17].

Any solid fuel released when releases carbon monoxide (CO) burned and carbon dioxide (CO2). As we all know, carbon monoxide (CO) is toxic, and it is also known as the "silent killer". The explanation behind this is that hemoglobin is over 200 times more attracted to carbon monoxide. It binds more strongly than oxygen, and so the blood will be deprived of oxygen.

There are effective ways of curbing household pollution. The practical solution is to develop a fuel-efficient stove and oven. Proper ventilation must be applied when cooking or baking indoors to get rid of intoxication inside the building.

Selected principles of Dr. Larry Winiarski (Aprovecho Research Center) in his "Design Principles for Wood Burning Stoves" were relevant to the development of the oven. According to him, good draft, controlled air intake and exhaust, and the use of a grate can support good combustion [19].

Ensuring one's health is also one of its concerns. When burned, coconut husk emits thick smoke due to incomplete combustion where poisonous carbon monoxide and hydrocarbons are emitted [20]. It poses a health risk such as respiratory disease—worse is intoxication. It is consumed easily by fire, so a considerable amount is required for baking. It is burdensome for the bakers because they must store sacks of coconut husk and bring these bulky cargoes to their baking area. Normally, they are mobile vendors because they go to a place where there is a big gathering, like a fiesta celebration.

Combustion efficiency alone does not guarantee fuel economy. Improving heat transfer efficiency makes a difference. Proper positioning of the charcoal trays and oven cavity was vital. The charcoal trays were placed near the surface of the oven cavity to maximize heat conduction. The heat produced by the burned charcoal was fully utilized, thus increasing the heat transfer efficiency.

There are three (3) ways heat transfers to another object or surface. They are conduction, convection, and radiation. These all happen at once in the oven.

A small opening at the bottom of the oven for air intake as well as on its upper-right and left sides for exhaust were provided. The draft inside the heat chamber supported proper combustion. Holes were added onto the back and right side of the oven as secondary air supply.

Soot, water vapor, and carbon monoxide are produced if the air supply is limited. Soot or thick smoke is the only indication that the oven performs poorly. It serves as insulation inside, preventing good thermal conductivity.

The air inside the burner and the hot gasses that come out are also controlled to prevent heat loss. Too little air will restrict combustion and the formation of carbon monoxide.

It should be avoided for its high toxicity [21].

A research paper on the "Design and Construction of a Small-Scale Charcoal Baking Oven" by Kulla, D.M. et al. is a simple design suitable for small-scale bakery businesses. It is portable and has only one fuel tray located at the bottom that can be pulled to the left side [22]. However, it needs some modifications to improve its performance and ergonomics. It lacks an ash receptacle, so the ashes will scatter beneath the oven and the floor where it stands will become messy. The cavity has a sliding door which does not make it sealed enough when closed. For easy opening, taking in and out the baking tray, the down-swing door is ideal. Aside from that, it has no separate chamber inside to isolate the food so that it will be freed from possible intermixing with smoke and particulate matter.

The design of the innovated fuel-efficient oven supported complete combustion. Exact amount of air was accommodated inside the oven then mixed it to burned charcoal to maintain its glow until it turned into ashes. The working principles of designing an efficient oven were applied. Its every detail was guided by the principles used in this research.

The innovative fuel-efficient oven design features were based on the principles of complete combustion and heat retention. Below are detailed presentations of how the principles were applied in the design process.

Maintain a good draft. A draft is a flow of gasses during combustion inside the oven. It can be done either naturally or mechanically (using a fan) or even both. In terms of its design, the oven used only the natural draft. This was achieved by supplying enough air in the combustion chamber.

It started from its air intake passages, from the bottom and side holes then going out to its exhaust. The volume of air that went inside and outside was controlled to avoid heat loss. Spaces were provided inside for the hot air to flow.

One of the most effective ways of getting air through the fuel was by providing grates. They were frames with slits and holes that held the burning fuel. Complete combustion

occurred. Air from below went through them and then mixed directly into the burning fuel. It also prevented the ashes from accumulating in the fuel tray.

Making a working drawing is vital in every manufacturing industry. It is a guide to how things are to be done. an extension of human's inability to visualize images in the mind [23]. A communication medium among designers and between the fabricators. The design consisted of different processes, the making of orthographic drawings, sections, details, and pictorial drawings of the oven. The symbols and measurements were accurate and consistent with industry standards. The tools used in the production, materials, and fabrication specifications were incorporated in the working drawing. With this, waste was eliminated, and production delays were also prevented.

The final step in the design process was prototyping. The product concept was created to evaluate its functionality according to specifications and make necessary adjustments for the improvement of the model. Prototype development and fabrication turned ideas into reality. They covered different activities like blueprint reading, layout, cutting, and assembling.

Ergonomics was integrated into every design. Parts were properly arranged so that it would be easy and safe for people to use. All requirements were complied with by outfitting it with two (2) overlay-drawer trays as fuel containers. Through this, refueling became handy and kept someone from getting burned. They were placed on top and bottom of the cavity to simulate the baking conditions of a rice cake. They had to be pulled to the left side of the oven for refueling. The faces of the drawers covered the whole side, preventing heat loss. Floor grates were provided for both of them, with slits and holes enough for the ashes to fall and air to enter to maintain complete combustion. Only one (1) ash receptacle was placed underneath the second or bottom overlay-drawer fuel tray. Its exhaust was located on the upper right and left sides of the oven. They were small openings that extended from their front to back edges. Tiny drilled holes were arranged at the back and right sides of the body to secure a constant air supply. Occupational health and safety (OHS) in metal fabrication and welding were implemented during the prototyping to avert injury or loss of life. Using the right tool and equipment for a specific job and wearing personal protective equipment (PPE) were administered. The ovens used in established bakeries are costly. The price range is from Php 5, 000.00 to almost Php. 200,000.00. Small-scale bakeries have difficulties acquiring them. It really needs a lot of capital to put up a bakery business. In public high school laboratories, the range is the most common appliance because it is affordable.

2. The Problem

2.1 Statement of the Problem

The study aimed to fabricate and evaluate a portable and fuel-efficient charcoal oven ideal for mobile vendors in Danao City, Cebu, Philippines. Specifically, it answered the following questions:

1) What are the technical requirements for the fabrication of charcoal oven as to its:
   1.1 design,
   1.2. tools, equipment, and materials needed,
   1.3. ergonomics, and
   1.4. safety?
2) As perceived by the users and experts, to what extent is the acceptability of the charcoal oven as to the following innovative factors:
   2.1. relative advantage,
   2.2. compatibility,
   2.3. simplicity,
   2.4. trialability, and
   2.5. observability?
3) Is there a significant mean difference between the perceptions of the respondent groups on the acceptability of the charcoal oven?

2.2 Statement of Hypotheses

The given hypotheses were tested at alpha level 0.05 of significance.

H_o: There is no significant mean difference between the perceptions of the respondent groups to the acceptability of the innovated fuel-efficient oven.

H_a: There is significant mean difference between the perceptions of the respondent groups to the acceptability of the innovated fuel-efficient oven.

3. Methods

3.1 Design

A survey methodology was used to collect data in order to get answers to the problems presented.

The first part was intended for the experts on the technical requirements for the fabrication of the oven. It pertained to its design, tools, equipment, and materials used; ergonomics, and safety measures employed during its fabrication. The second part was on the perceptions of the two respondent groups on its acceptability, following the five (5) innovation qualities that influence adoptability from the "Diffusion Innovation Theory". Their perceptions were evaluated and compared afterwards.

3.2 Flow of the Study

It hinged on the Diffusion of Innovation Theory of Dr. Everett M. Rogers. It is about the five main factors that lead to the adoption of innovation.

The theory is substantiated by the Principles for Wood Burning Stoves by Dr. Larry Winiarski. Some of them were essential in the oven design process. Moreover, significant information from other studies was incorporated to produce a sound design. Ergonomics were also given importance to make the bakers comfortable while baking.

The conceptualization of the design was based on theories, principles, and related studies about the charcoal stove and oven. The preliminary procedures were complying with the technical requirements. The design was created first. It included the preparation of drawing plans, starting from the orthographic drawing, to section, details, and pictorial drawing. The ANSI drawing standard was applied in the working drawing. The next step was making a list that covers the selection of the right-hand tools, power tools, equipment, supplies, and materials. Ergonomics was taken into consideration for convenience.

Personal protective equipment (PPE) used in the fabrication was specified for the safety of the workers. Production of the prototype followed thereafter. Upon completion, the bakers/vendors and experts validated its acceptability. Then the data from the survey was interpreted as to the acceptability of the oven.

Producing fabrication and user manuals were the outputs of the study. They served as a guide for creating, using, and maintaining the oven. The fabrication manual included the working drawings, materials, tools, equipment, and fabrication methods applied. In the user's manual was the proper use and maintenance.

3.3 Respondents

There were two (2) respondent groups involved; the bakers and experts (composed of engineers, draftsmen, and welders). Each group was composed of 10 persons with a total of 20.

Table 1: Distribution of Respondents

Respondents	N
Bakers	10
Experts	10
Total	20

3.4 Instrument

The descriptive method was used to acquire the data. The questionnaire was the main instrument, with the Likert scale as a measuring tool for determining respondents'perceptions. It was distributed to them during the testing and immediately retrieved when they were done.

3.5 Statistical Treatment of Data

The qualitative data were extracted from the survey questionnaire about the respondents' perceptions of the oven's acceptability.

The questionnaire was divided into two parts. The first part was about the technical requirements for the fabrication of the charcoal oven, which were to be filled out only for the experts group. Weighted mean was used to calculate the average value of the data.

The second part was about the perceptions of both groups—the bakers and the experts. It used an Independent Samples t-test to compare the means of the two groups.

3.6 Scoring Procedure

The questionnaire was composed of two (2) parts. The first part was directed at the innovative fuel-efficient oven's technical requirements: the working drawing, tools, equipment, materials needed, ergonomics, and safety. Only the experts were given the task of rating the technical requirements because it was their field of expertise. In the second part, both the bakers and experts evaluated its acceptability in terms of relative advantage, compatibility, simplicity, trialability, and observability. Each other's results were compared thereafter.

Below is the guide to how the oven was rated on its acceptability during the evaluation. It used the Likert scale, with a range from one (1) to five (5).

Range of Scores	Descriptive Rating	Verbal Interpretation
4.21-5.00	Highly Acceptable	When the quality of output, performance, or condition is excellent.
3.41-4.20	Moderately Acceptable	When the quality of output, performance, or condition is good.
2.61-3.40	Acceptable	When the quality of output, performance, or condition is fair.
1.81-2.60	Less Acceptable	When the quality of output, performance, or condition is poor.
1.00-1.80	Unacceptable	When the quality of output, performance, or condition is very poor.

4. Results

4.1 Technical Requirements for the fabrication of charcoal oven

4.1.1Design

Design starts with the creation of a plan. It is a representation of the final design (the output or product) that is to be manufactured or fabricated. It is a graphical language that transfers ideas from one person to another. It is a clear and concise way of communicating all the information relevant to transforming an idea into reality. This transformation process covers manufacturing assembly, construction, or fabrication. A good technical drawing gives complete information by itself and does not require the designers or drafters to provide additional information or further clarification to the fabricator [24].

There are a set of rules for how the drawing should appear. These are the standards that should be applied to every working drawing. The standards are formulated in order to get rid of disagreements so that people of different nationalities can understand simply by looking at the universal symbols and conventions.

The American National Standards Institute (ANSI) is the U.S. member body of the International Organization for Standardization (ISO). The former indorses North American standards, whereas the latter indorses global standards. The ISO is the international standard-setting body with representatives from various national standard organizations

(www.iso.org). There is no conflict between the two organizations; in fact, both of them go hand in hand in harmonizing international standards.

There is almost no deference between the two drawing standards other than the first against the 3rd angle projection.

The acceptability of the design was constituted by the innovative fuel-efficient oven's working drawings, from the basic supplication of mechanical drawings with their corresponding measurements for the purpose of guiding the fabricator in its construction. The expert respondents rated the working drawing in accordance with the ANSI standard.

Table 2 reveals that the selection of views presented in the working drawing was appropriate. The details were enough to guide the fabricator in constructing the oven. Most of the ANSI standards in drafting were followed.

On top was the "Orthographic, pictorial, and sectional views are clear". The 3rd angle projection was used. Usually, three views would suffice; however, the left-side view was included because its features were different from the opposite side, followed respectively by "Drawing details are adequately presented", and "American National Standard Institute (ANSI) drawing standard is strictly followed". All three items (3) were highly acceptable, with weighted means of 4.80, 4.70, and 4.50

The average weighted mean of the three (3) items was 4.67, which is highly acceptable, which means that all of them adhered to the ANSI drawing standard. The lines, dimensions, as well as the views in the orthographic and pictorial drawings were clear. They represented correctly the real shape and size of the innovative fuel-efficient oven.

Table 2: Design (n=10)

Design	$\bar{x}$	Verbal Description
Orthographic, pictorial, and sectional views are clear.	4.80	Highly Acceptable
Drawing details are adequately presented.	4.70	Highly Acceptable
American National Standard Institute (ANSI) drawing standard is strictly followed.	4.50	Highly Acceptable
Average Weighted Mean	4.67	Highly Acceptable

4.1.2Tools, Equipment, and Materials Needed

Tools and equipment are vital. They can be found in the working drawing. They are responsible for transforming the materials into desired shapes. They are evolving because people have been constantly looking for ways to make their lives better, as history attests the way tools have improved over time. They have even become sophisticated nowadays. Each tool's design is dependent on the unique task it must accomplish [25].

The bill of materials (BoM) is an invaluable source of material quantity information for the estimator. Without it, one lacks the ability to read the comments, particularly the sizes, types, and amounts of materials required based on the product specifications [26]

Table 3 identifies that the "Use of right and standard materials" had a weighted mean of 5.00-highly acceptable. The "Availability of tools, materials, and equipment" had a weighed mean of 4.60-highly acceptable. The average weighted mean was 4.80-highly acceptable.

Table 3: Tools, Equipment, and Materials Needed (n=10)

Tools, Equipment, and Materials Needed	$\bar{x}$	Verbal Description
Use of right and standard materials.	5.00	Highly Acceptable
Availability of tools, materials, and equipment.	4.60	Highly Acceptable
Average Weighted Mean	4.80	Highly Acceptable

4.1.3Ergonomics

The main purpose of incorporating ergonomics into every tool, equipment, machinery, appliances, etc. is to bolster productivity without sacrificing comfort for the user. It is important because the human body cannot stand long enough if it is stressed by an awkward posture, extreme temperature, or repeated movement of the musculoskeletal system. It begins to experience fatigue, discomfort, and pain. There are three aspects of ergonomics: physical, cognitive, and organizational. Reactions of the human body to physical and physiological work demands are physical ergonomics. Cumulative repetitive tasks lead to health problems. A demanding task that entails risk should be ergonomically sound to prevent accidents [27].

Table 4 indicates that the operation that was performed during the testing was the changing of trays. The "Ease of putting in and getting out of the baking tray" received a 4.80 rating, which was highly acceptable. "Comfortability in refueling" and "Portability" with a similar score of 4.70 weighted mean-highly acceptable. The last was the "Ease of cleaning and maintaining the part", with a weighted mean of 4.50-highly acceptable.

The average weighted mean was 4.68-highly acceptable. It showed that it was ergonomically sound. The parts of the oven that the baker was constantly operated were its drawers for the fuel and door. The respondents were satisfied with its features. The drawers really helped a lot; they made refueling easy and safe. It was portable due to its small size

Table 4: Ergonomics (n=10)

Ergonomics	$\bar{x}$	Verbal Description
Ease of putting in and getting out the baking tray.	4.80	Highly Acceptable
Comfortability in refueling.	4.70	Highly Acceptable
Portability.	4.70	Highly Acceptable
Ease of cleaning and maintaining the parts.	4.50	Highly Acceptable
Average Weighted Mean	4.68	Highly Acceptable

4.1.4 Safety

It is the standard operating procedure in every shop. Life and health must be given the utmost importance.

The reason why workers are obliged to use PPE. Not only that, they must also follow standard procedures in order to avoid accidents. Using the right tool for a specific job is a

safety procedure by itself. In this way, injuries can be prevented, and productivity is increased.

Proper housekeeping is also very important. Cluttered materials, and spills are health hazards due to slips, trips, and falls. An orderly shop contributes to high efficiency. It is easy for the worker to access the tools and materials because they are properly organized and placed in a designated area. Looking for something that is put in an obscured location is a waste of time.

One good example is the Japanese time-tested 5s technique, the seiri (sort), seiton (straighten), seiso (sweep), seiketsu (standardize), and shitsuke (sustain). This is not limited only to housekeeping but also on maintaining the standards and discipline necessary to manage the organization in all sectors.

There are many benefits it can offer. It improves safety, forms a foundation as a basis for further improvements, reduces waste, boosts workers' sense of ownership through involvement and responsibility, and improves performance in productivity, quality, and morale, which leads to increased profitability. This can only be achieved by upholding and showing respect of the workplace every day. This has been proven to be effective and has been adopted by many industries around the world [28]

Table 5 shows that "Proper housekeeping of the working area" ranked first with a weighted mean of 5.00-highly acceptable, "Adequate ventilation of working area" with a weighted mean of 4.90-highly acceptable, "Wearing of personal protective equipment (PPE) and clothing with a weighted mean of 4.80-highly acceptable. Last in the list was the "Proper use of tools and equipment" with a weighted mean of 4.60-highly acceptable. The average weighted mean was 4.83 - highly acceptable.

Table 5: Safety (n = 10)

Safety	$\bar{x}$	Verbal Description
Proper housekeeping of the working area.	5.00	Highly Acceptable
Adequate ventilation of working area.	4.90	Highly Acceptable
Wearing of personal protective equipment (PPE) and Clothing.	4.80	Highly Acceptable
Proper use of tools and equipment.	4.60	Highly Acceptable
Average Weighted Mean	4.83	Highly Acceptable

4.2 Summary Table on The Technical Requirementsin Terms of the Fabrication of the Innovative Fuel-Efficient Oven

Table 6 shows that the average weighted mean in "Design" was 4.67—highly acceptable. "Tools, Equipment, and Materials Needed" was 4.80-highly acceptable, "Ergonomics" was 4.68-highly acceptable, and "Safety" was 4.86-highly acceptable.

The overall average weighted mean was 4.67-highly acceptable.

Table 6: Summary Table on the Technical Requirements Terms of the Fabrication of the Innovative Fuel-Efficient Oven

Technical Requirements in Terms of the Fabrication of the Innovative Fuel-Efficient Oven	$\bar{x}$	Verbal Description
Design	4.67	Highly Acceptable
Tools, Equipment, and Materials Needed	4.80	Highly Acceptable
Ergonomics	4.68	Highly Acceptable
Safety	4.83	Highly Acceptable
Average Weighted Mean	4.75	Highly Acceptable

All four (4) technical requirements were complied with as presented in table 6, each receiving a highly acceptable rating.

During its construction, the fabricators had an easy time creating their parts and putting them together by relying on the working drawings handed to them. Tools, equipment, and materials were all available. Tools and equipment were used properly; the materials procured were of good quality and conformed to the required specifications.

This oven was portable and light; thus, it met the mobile baker's needs. Parts were ergonomically sound and safe to operate. Fabricators wore personal protective equipment and clothing. They followed all safety procedures in metal fabrication. There was no untoward accident that occurred during the fabrication process. Proper housekeeping was implemented after every day's work.

4.3 Perceptions of the Respondent Groups Toward the Acceptability of The Innovated Fuel-Efficient Oven

4.3.1Relative Advantage

It is about having an edge or appeal over the other products or ideas. The rate of adoption greatly depends on its relative advantage as perceived by the prospective adopters or customers.

It had three advantages: efficient fuel use, minimal smoke emissions, and good heat retention, and these three characteristics worked synergistically. Because the charcoal oven retained heat well, less fuel was required. It was also an indication that the fuel was completely burned. The less smoke, the more heat was produced. This was how the fuel-efficient oven worked. Reducing the smoke haze would contribute to significant health benefits for the bakers.

In table 7, the data taken from the two (2) groups of respondents is placed side by side in one table for easy comparison. This is applied to the subsequent tables.

The table shows that both respondent groups had similar perceptions. Top on the list was the "Heat Retention", with a 4.80 weighted mean in the bakers' group and a 4.50 in the experts' group, which was highly acceptable. The other two items, "Low Fuel Consumption" and "Less Smoke Emission" had the same weighted mean of 4.70-highly acceptable by both bakers and experts. The bakers' average weighted mean was 4.73-highly acceptable, whereas the experts was 4.63-

highly acceptable.

Table 7: Relative Advantage (n = 20)

Relative Advantage	Bakers (N1 = 10)		Experts (N2 = 10)	
	$\bar{x}$	VD	$\bar{x}$	VD
Heat retention	4.80	HA	4.50	HA
Low fuel consumption	4.70	HA	4.70	HA
Less smoke emission	4.70	HA	4.70	HA
Average Weighted Mean	4.73	HA	4.63	HA

4.3.2 Compatibility

It is about the connection of the existing values, previous experiences, and needs of the would-be adopters.
Charcoal as the main fuel used in the oven is one of the dominant fuels in Cebu province.

It is most preferred by lower-income households. Aside from that, it is used commercially, such as in barbeque stands, lechon grills, bakeries, and restaurants [29]. It is a simple and easily accessible type of fuel.

The oven cavity was distinct from another conventional oven because of its short with just 5.50 cm. to include rice cake. It was deliberately designed to be small so that it could be set up easily and be transported immediately. Portability was achieved by using charcoal as fuel. It was ideal for mobile bakers/vendors.

Table 8 reaffirms the importance of the transportability of the oven since it was what the bakers' group wanted. In the baker's group, the "Ease of handling" had a weighted mean of 5.00-highly acceptability. In the experts' group the weighted mean was 4.90-highly acceptable. In "Bakes efficiently", the weighted mean was 4.90 for the bakers and 4.80 for the experts; both were highly acceptable. The bakers' average weighted mean was 4.90-highly acceptable, whereas the experts was 4.80-highly acceptable.

Table 8: Compatibility (n = 20)

Compatibility	Bakers (N1 = 10)		Experts (N2 = 10)	
	$\bar{x}$	VD	$\bar{x}$	VD
Ease of handling (Portability)	5.00	HA	4.90	HA
Bakes efficiently	4.80	HA	4.70	HA
Average Weighted Mean	4.90	HA	4.80	HA

4.3.3Simplicity

The items in simplicity are derived from the technical requirements in terms of ergonomics. It is about the simplicity of how it is being operated.

Drawers for fuel were very helpful for the bakers when refueling. It made their baking experience more comfortable and satisfying; thus, baking became enjoyable. They put in a few pieces of charcoal during refueling just to maintain the temperature.

Table 9 reveals that the weighted mean of "Ease of refueling" in the bakers' group was 5.00, and in the experts group it was 4.70**,** both highly acceptable. "Ease of changing baking tray is both 5.00-highly acceptable in the bakers and experts' groups. "Ease of cleaning the fuel trays, ash receptacle, and oven cavity" was 4.70-highly acceptable in bakers and 4.80-highly acceptable in experts. The average weighted mean in bakers was 4.90-highly acceptable and 4.83-highly acceptable in experts.

Table 9: Simplicity (n = 20)

Simplicity	Bakers (N1 = 10)		Experts (N2 = 10)	
	$\bar{x}$	VD	$\bar{x}$	VD
Ease of refueling	5.00	HA	4.70	HA
Ease of changing baking tray	5.00	HA	5.00	HA
Ease of cleaning the fuel trays, ash receptacle, and oven cavity	4.70	HA	4.80	HA
Average Weighted Mean	4.90	HA	4.83	HA

4.3.4 Trialability

It is about easiness in operating the oven. Unlike in gas and electric ovens, their temperatures can be set easily by just turning the temperature knob. When adjusting the charcoal oven's temperature, the amount of fuel should be controlled during its feeding. For the first-time user, determining the heat temperature is somewhat complicated and challenging. But this is overcome when one is adept at it already.

That issue was addressed by installing a thermometer in the oven's door in order to determine the temperature inside the cavity. The baker had the flexibility to experiment in terms of different baking conditions on different kinds of food.

Table 10 shows that both respondent groups had the same perceptions on "Ease of Operation for First-Time Users" with a weighted mean of 5.00-highly acceptable.

Table 10: Trialability (n = 20)

Trialability	Bakers (N1 = 10)		Experts (N2 = 10)	
	$\bar{x}$	VD	$\bar{x}$	VD
Ease to operate for first-time users during testing.	5.00	HA	5.00	HA

4.3.5 Observability

It is the overall performance that manifests in terms of its convenience and efficiency. This is about the user's experience, wherein it associates one's emotions and attitudes with using the product. A product that meets the needs and expectations of the user and leads to a satisfying result. There is a considerable chance that an innovation will spread rapidly to the target population if the benefits are visible.

Observability of the innovated fuel-efficient oven was based on its ergonomic design, prolonged heat retention, low fuel consumption, and less smoke emission. These characteristics could be summed up into two categories: ergonomically sound and fuel-efficient. They were the evident results, as expected since its inception.

With reference to the results during the testing. It met the bakers' expectations in ergonomics, portability, and fuel efficiency. The respondents were satisfied with the outcome. Based on the data gathered, which is reflected in Table 11, the weighted mean of the item "Fuel efficient and convenient to use" in bakers was 4.70-highly acceptable and in experts it

was 4.50-highly acceptable.

Table 11: Observability (n = 20)

Observability	Bakers (N1 = 10)		Experts (N2 = 10)	
	$\bar{x}$	VD	$\bar{x}$	VD
Fuel efficient and convenient to use.	4.70	HA	4.50	HA

4.4 Summary Table on Acceptability

Table 12: Summary Table on the Acceptability (n = 20)

Perceptions of the Respondent Groups	Bakers (N1 = 10)		Experts (N2 = 10)	
	$\bar{x}$	VD	$\bar{x}$	VD
Relative advantage	4.73	HA	4.63	HA
Compatibility	4.90	HA	4.80	HA
Simplicity	4.90	HA	4.83	HA
Trialability	5.00	HA	5.00	HA
Observability	4.70	HA	4.50	HA
Average Weighted Mean	4.84	HA	4.75	HA
Standard Deviation	.14		.18	

4.5 Test of Significant Mean Difference BETWEEN the Perceptions of the Bakers and Experts Respondent Groups of the Innovated Fuel-Efficient Oven

Table 13: Test of Significant Mean Difference between the Perceptions of the Bakers and Experts Respondent Groups of the Innovated Fuel-Efficient Oven

Perceptions	Bakers n=10		Expert n=10		Computed t-value	Critical p-value df=18, α=0.05 two-tailed test	Decision
	X1	SD1	X2	SD2			
Acceptability	4.84	0.14	4.75	0.18	0.23	0.05	Failed to Reject Ho

A t-test was used in testing for the significant difference. The average weighted mean and standard deviation were computed and recorded.

Table 13 presents the result of the Significant Difference between the perceptions of the bakers and experts on the innovative fuel-efficient oven. For the bakers, the weighted mean was 4.84, with a standard deviation of 0.14. On the other hand, the expert weighted mean was 4.75, with a standard deviation of 0.18. The 0.23 computed p-value was between the perceptions of the respondent groups to the acceptability of the innovative fuel-efficient oven. "was accepted."

The bakers and experts had similar perceptions of the acceptability of the innovative, fuel-efficient oven. In all five (5) characteristics, their perceptions were highly acceptable.

It achieved its goal of providing for the baker's needs. It greater than the alpha level of 0.05. Therefore, the null hypothesis, Ho: "There is no significant mean difference a was determined based on their satisfaction with considerations of the desired characteristics in terms of the technical requirements and acceptability, thus coming up with the expected outcome that centers on the baker's convenience that made the fuel-efficient oven adoptable.

4.6 Illustration

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