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DEVELOPMENT OF BIODEGRADABLE RIGID PACKAGING FROM VEGETABLE PEELS INTEGRATED WITH CHITIN

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Abstract: utilization of the vegetable waste and their remains are a bigger challenge to the food industry. The vegetable peel waste is considered a potential source of ingredients for food packaging. The main idea of this research project is to focus on the utilization of the vegetable peel waste in developing it into a biodegradable rigid packaging material that will be further integrated with chitin extract. Chitin is used as the major binding agent in this development process. The strong cellulose component present in chitin will act as a great support to the rigid package material. Also, it will have better rigidity and stability. Chitin is chosen because of its high thermal stability, tough strength, tensile character, and biocompatibility and also because of its naturally occurring biopolymer. We intend to create biodegradable packaging as a new trend with the integration of vegetable peels and chitin. The shelf life, biochemical and certain physical parameters of the developed packaging material have also been tested and analyzed. Thus, we insist on developing an eco-friendly packaging system to reduce the sustaining harmfulness in the environment around.

Keywords- vegetable peel, chitin extract, biodegradable, packaging, eco-friendly, rigid package, packaging trend.

I. INTRODUCTION

Land and environmental pollution are one of the major problems faced on our planet today. Land pollution is a global problem and is common in both developed and developing countries. Food packaging is important for product integration, preservation, and protection, reducing food spoilage, eliminating the risk of adultery, and delivering food cleanly and attractively. Packing plays a major role in the protection of health in the production of food products. Plastic-based packaging has been widely used for decades. Over the past 50 years, the global production of plastics i.e., carbon-based polymers such as polypropylene, polyethylene, polyvinyl chloride, polystyrene, nylon, and polycarbonate, has continued to grow as easily as possible in the product development list appropriate for their lightweight, flexibility, and durability. However, high levels of plastic waste production are one of the world's most pressing issues both in terms of environmental issues and endanger human health. The reuse of plastic waste is not a permanent solution for the vegetable and fruit industries especially. The use of this waste is a major challenge in the food industry and researchers have developed non-waste technologies in the agricultural and food processing industries. Thus, the use of vegetable peel as a packaging material can easily be reduced and becomes a natural fertilizer in the natural world. The production of edible biodegradable packages is the latest way to create food-safe packaging for humans and the environment. Perishable packages have physicochemical and mechanical properties suitable for replacing conventional plastic applications. However, the food industry faces several challenges ranging from climate change, rising consumer safety requirements, and subsequent problems related to government policies and legal requirements. As a result, there is a growing need to replace plastic materials with perishable materials. This project aims to develop decomposable rigid packaging made of vegetable and waste products then analyze their quality parameters. Chitin is a complex interconnected homopolymer found in many species of organisms such as crab and shrimp shells, insect exoskeletons, nematode eggshells, and fungal cell walls (mushrooms). The structures are composed of microcrystals polymer N-acetyl-D-glucosamine. This is considered the second-largest cellulose in the world. Chitin is used as a binding agent as it has high thermal strength and strong strength. In addition, their use in food packaging systems acts as antioxidants and antimicrobial supplement carriers and improves food storage as they are able to extend shelf life. This destructive packaging also contains biosensors filled with the role of an index, which changes color under the influence of external factors and reflects the life span of building materials. Shelf life lessons are designed to pack and store food products.

II. RESEARCH OBJECTIVES

The key objectives of the project are,

- To form the base pulp by integrating vegetable peels wastes and chitin.
- To check for the suitable combinational ratio required.
- To mold the blended materials into a rigid package.
- To assess the engineering and biochemical changes in the package.

III. RESEARCH METHODOLOGY

3.1 MATERIALS USED

The major materials used in this research product development are like the peels and wastes of Beetroot [Beta vulgaris a subfamily Betoideae of the family Amaranthaceae], Carrot [Daucus carota subspecies]. Sativus belonging to the family of Apiaceae with order Apiales], Garlic [Allium sativum, sp of Allium, belonging to the Amarilydaceae family with order Asparagales], Potato [Solanum tuberosum of family Solanaceae in the order of solanels], Ginger [Zingiber officinale of the order Zingiberales], Chitin $(C_8H_{13}O_5N)_n$ is a long-chain polymer of N-acetylglucosamine, a derivative of glucose., Gelatine is a translucent, colorless, flavorless food component, which is obtained from the animal body collagen. The texture is also almost brittle in the dry state and greasy in the moist state.

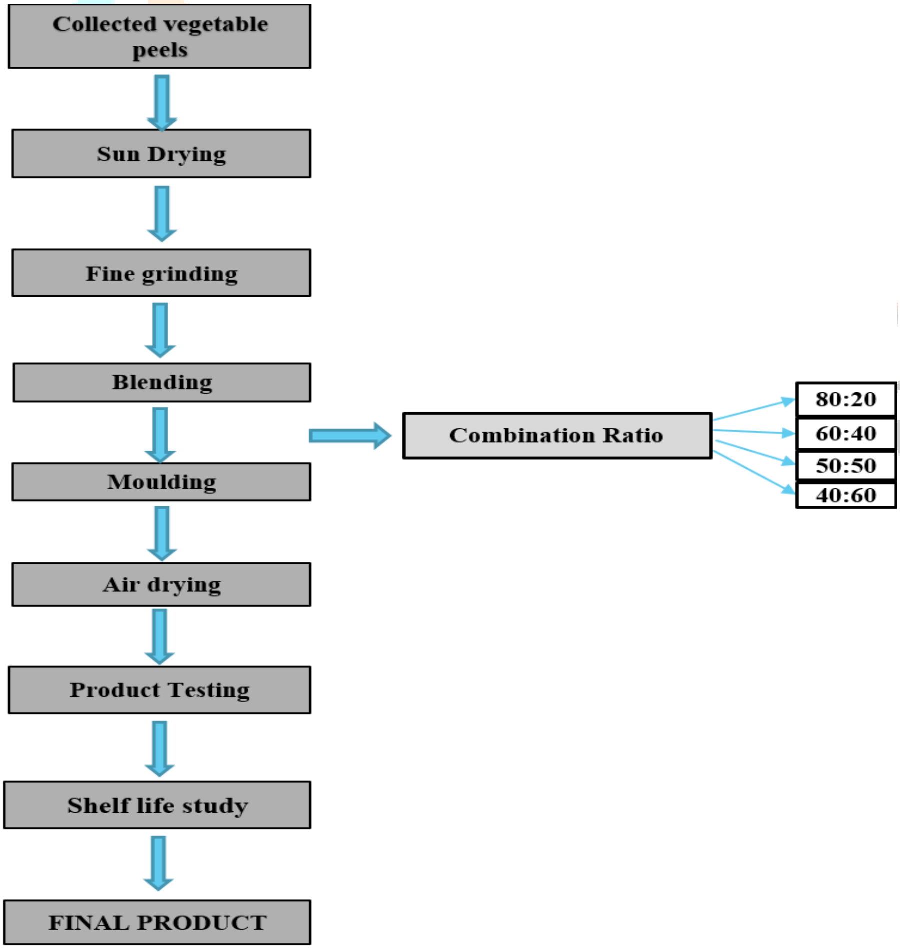

Fig.3.1 Process flow of development of biodegradable rigid package

3.2 PREPARATION OF WASTE VEGETABLE PEELS POWDER

Processing and utilization of vegetables alone generate a very significant amount of waste of the total product. Most common vegetable wastes include the pomace, peels, rind, and seeds. These are rich in valuable bioactive compounds such as the carotenoids, enzymes, polyphenols, oils, vitamins, and many other compounds. The collection of the vegetable wastes was initially started from the very household wastes. The collected peels were stored below room temperature for two days to freeze their compound values and avoid decomposition. When the desired quantity was obtained the peels were altogether spread on a spacious plate surface and sun-dried for another four days countably. The pals have to lose all of their moisture content to obtain fine quality powder form.

3.3 GRINDING AND GELATINE PREPARATION

The process of grinding is an abrasive machining process that uses a grinding wheel as the major cutting tool. Various varieties of appliances can be used for grinding purposes like grindstones, handheld power tools such as angle grinders and die grinders, etc. Here, the home grinder has been utilized in order to produce a very fine powder substance. The speed of the grinding tool has been implicated in the nominal speed of 11,500rpm in a loaded condition. The preparation is set aside and the gelatine mixture was prepped then. In order, to dissolve the gelatine, the double boiling method has been used. By placing cold water in a small bowl and it was sprinkled with gelatine while whisking continuously. Then set aside for 5 minutes until becoming spongy. Later, standing the gelatine bowl in a heatproof bowl of hot water it is stirred well until dissolved. Boiling gelatine can detain it from its original stand of action.

3.4 DETERMINING COMBINATION RATIO

Any material to combine has to go through various combination trials, just in order to finalize the quality, stability both mechanically and biologically. In that case, conventional preparation methods use specific ingredient measurements, the combination ratios have always been a fixed proportion of ingredients that are in relation to one another and vice versa. Instead of measuring by grams, cups, or pounds, ingredients have been defined in *"parts"* that are again relative to each other in quantity. These ratios helps in production which is easy ink scaling the desired quantity. The final product quality has been evaluated through ratio analysis to test for accuracy. In such a case, the combination ratios that the stated product has undergone are in four various ratios. The ratios have been set up in different proportions to calculate the product stability and bring out the best finish. The ratios that we have used areas,

- **MIXTURE 1-** (R_1 80:20) eighty parts of vegetable peels powder combined with twenty parts of chitin binding agent.
- **MIXTURE 2-** (R_2 60:40) sixty parts of vegetable peel powder with forty parts of chitin agent.
- **MIXTURE 3-** (R_3 50:50) equal parts of vegetable peels powder with that of the chitin binding agent.
- **MIXTURE 4-** (R_4 40:60) forty parts of peels powder mixed with sixty parts of chitin.

The above trials have been performed to attain the perfect desired quality.

3.5 PRODUCT MOLDING

Molding is usually the method of developing any product by shaping liquid raw material into the desired product using a mold or even die. This by itself counts to have been made using a pattern or model of the final object. It can also be subjected as a hollowed-out block which will be filled with the liquefied or pliable raw material (vegetable peel powder, chitin powder, liquid gelatine). The liquid hardens and sets inside the mold adapting to its shape. The mold actually plays the most important part in casting. The same working process has been taken up in this manufacturing process. The product has been molded in a rectangular shape. It is so to bring out the spacious and defined package material.

3.6 STUDYING SHELF LIFE AND PRODUCT TESTING

Shelf-life studies play a very critical role in the development of our new product. It plays a much larger role in the product quality life-cycle too. Genuinely conducted shelf-life studies ensure that the product quality will be maintained throughout the product life-cycle and also helps in greatly reducing the chances of customer complaints related to quality. In support of that, we have equally concentrated on the very part of shelf life analysis too, to carry out the best analyzing method. The molded food package was studied by having various food samples in it to ensure the span of stability. To ease the method, the shelf life study was performed with three types of food products classified on the basis of their perishability. Apart from shelf-life analysis, the product has also undergone various biochemical and mechanical testing. These were carried out to learn in-depth about the product standards and quality.

3.6.1 Water Absorption Test-

All the prepared samples were tested to obtain the total water absorption value. The rigid package samples were weighed separately prior to immersion in the distilled water. Subsequently, the packages were immersed in water for more than an hour. The final weights were then recorded. The surfaces were wiped until they became dry. The water absorption index was calculated for the prepared samples. The value of water absorption (%) was calculated according to the equation below,

$$W_{t.}\ (\%) = [(W_a - W_o) / W_0] \times 100$$

Where, Wt = total water absorption, W_a = weight of sample after immersion in water and W_o = original weight of sample before immersion.

3.6.2 Water Solubility Test-

All the prepared samples were experimented with to test the solubility rate of the prepared samples. The package samples were made to immerse inside water and were agitated to test the solubility and dispersion of the bound raw materials for one hour of time span. When the packages have high WS, they tend to easily dissolve in water, whereas the package with lower value has a better stability. The initial and the final weight of the package samples are noted. With the help of recorded values, the solubility index of the samples are calculated using the mathematical formula given below,

$$\mathbf{WS\ (\%) = [(W_i - W_f)/\ W_i] \times 100}$$

Where WS is solubility in water; W_i is the initial weight of the sample package; and W_f is the final weight of the sample package.

3.6.3 Drop Test-

The break test is the experiment conducted to test the strength of the material. It can also be said as the tensile or compressive load required to deform or fracture any material to make the sample break. So as it is, any rigid package has to undergo a brake test to maintain and prove its quality and to meet the required packaging standards. Here, we have made developed a rigid biodegradable package to test its breakability. The process was the experiment was to allow the product to fall from different set height parameters. Like, the heights were set from 6ft, 8ft, 10ft, and 12ft. as the products feel their result was observed and were recorded in a tabulated form. The longer they withstand the falling force the longer is their stability. Their make quality standard can be determined from this test method.

3.6.4 Leak test –

The method of leak test is to find if any product subjected is dense enough or has minimal air gaps. The leak can occur when there is any gas or liquid flows through that product due to poor manufacturing defect causing the crack, hole, or any weak seal. These defects can cause high and low-pressure zones inside the product, which allows air poor liquid to pass through. To test the leaking level the prepared package samples were filled with water to observe bubble formation. If there was an air gap there would be air bubbles formed in the top layer of the water. This will be due to the less density in the package that allows the respiration of air. On the other hand, if there isn't any bubble formation then it can be considered that the manufactured package sample is dense enough to withstand any penetration of air or liquid matters.

3.6.5 Biodegradability Test –

Biodegradability or composting ability is the ability of any substances (organic or natural) to be completely broken down when in contact with the environmental land surfaces. The breakdown of the materials takes place due to the organic enzymes present in the land. When this process is complete, there will be no trace of remains of the materials if it claims to be biodegradable or material made from natural components. In that case, the prepared sample packages were buried under the soil (10cm depth from the land). They were left undisturbed for 10 days. After the specific period, the samples were re-dug to check for degradability. If there is no trace of remains then it can be called completely biodegradable. If not then, the product cannot be claimed as biodegradable material.

3.6.6 pH Test –

The pH value usually determines the power of hydrogen, and it is a scale that is used to specify the acidity or basicity (alkalinity) of the solution. For the prepared samples, the sample was powdered and they were diluted to make it an aqueous solution so that the pH test can be done easily. Then using the pH indicator the level was determined. Knowing the pH level will help in idealizing the type of food product that can be stored inside the prepared packaging product. As we know, if the indication is below 7 it is acidic, and when it is above 7 then it can be declared basic. In another case, if it is in the range of range then the product can be considered neutral, which is desirable to store both acidic and basic food products.

3.6.7 Color Change Test -

The Color of any product is considered the very first parameter to attract consumers towards it. In the case of biodegradable packaging material, as these are made from completely natural ingredients, there are chances for color change in the appearance as the period prolongs. To test and analyze this, the prepared sample packages were studied under forced conditions for 10 days of due time to check for any changes in the color i.e., appearance-wise. If there is no color change ten it can be concluded that the product finely stable. Whereas, if there are any changes observed then they can be due to the excess moisture intake or other issues in the chemical composition and binding of the material. Hence, the color change test is one of the important parameters to determine the quality standards of the packaging material.

3.6.8 Shelf life study –

Apart from just testing the physical parameters shelf life study also plays an important role in maintaining the quality standards. Shelf life analysis have numerous tests to be conducted for the product to examine the changes with time and other environmental factors. These tests can even include chemical, sensory, analytical, and microbiological testing. Such tests can be performed for any food product. Here, as we have developed a packaging material the shelf life analysis procedure has been altered. Different food products based on their perishability has been stored inside the prepared packaging samples for almost 3 weeks of time. During this due period the changes where noted down.

IV. RESULTS AND DISCUSSION

The aim of this project was to manufacture a biodegradable rigid food package made from integrating vegetable peels and chitin. The package was successfully manufactured and has undergone various testing procedures and shelf life studies. The overall outcomes and test results have been discussed briefly below.

4.1 WATER ABSORPTION TEST

The water absorption value of all the prepared samples was tested. Refer to table 4.1. The sample package with the ratio of R_2 60:40 showed the least water absorption index of 1.1%, it was so because of the proper combination of binding agents (chitin and gelatine). Due to this, it is studied that, the density of the product pretty good and is moisture resistant. In comparison, with the other commercial bioplastics and biopolymers the wt% ranges from 0-29% *[E.H Wong, 2013]*. So, in context to that the prepared rigid bio package, has invariably an impressive range of wt% property.

Sample ratio	Initial weight of sample (g) W_o	Final weight of sample (g) W_a	Water Absorption (%)
80:20	83.5	85	1.7
60:40	**90**	**91**	**1.1**
50:50	87	88.1	1.2
40:60	90.2	91.6	1.5

Table 4.1. Water Absorption index of the various package samples

4.2 WATER SOLUBILITY TEST

The water solubility test for all the prepared samples was conducted. Refer to table 4.2. As chitin is naturally insoluble in regular solvents such as water, organic solvents, mildly acidic, or basic solution, it has shown the least water solubility value of 3.0%. Due to the high density and stability of the binding agents, the solubility range has been pretty low. Hence, the product sample with the ratio of R_2 60:40 shows the least solubility.

Sample ratio	Initial weight of sample (g) W_i	Final weight of sample (g) W_f	Water solubility (%)
80:20	83.5	80	4.1
60:40	**90**	**87.3**	**3.0**
50:50	87	83.7	3.7
40:60	90.2	86.9	3.6

Table 4.2. Water Solubility level of the sample packages.

4.3 DROP TEST

As one of the most important physical parameters, the break test for the samples was conducted and the results were recorded. Refer to table 4.3. As chitin already possesses the strong property of high tensile strength and, bio stability it was able to withstand the falling force from the test falling heights. Thereby, the sample ratios R_2 60:40, R_3 50:50, R_4 40:60 were able to maintain better stability.

Height (ft)	Sample	Fall Outcome
6	R_1 80:20	Stable
8		Stable
10		Broke
12		Broke
6	**R_2 60:40**	**Stable**
8		**Stable**
10		**Stable**
12		**Broke**
6	R_3 50:50	Stable
8		Stable
10		Stable
12		Broke
6	R_4 40:60	Stable
8		Stable
10		Stable
12		Broke

Table 4.3. Break Test results of the sample packages

4.4 LEAK TEST

As the leak test was performed manually by submerging the sample underwater for few minutes to check the presence of bubbles. During the test, it was found that no such bubbles were found in samples R_2 60:40. The other samples had few bubble formations. Due to the presence of air gaps and other particulate materials, bubble formation had happened. The results were recorded. Refer to table 4.4.

Sample ratio	Presence of bubble
R_1 80:20	More bubble were found
R_2 60:40	**No bubbles were found**
R_3 50:50	Few bubbles were found
R_4 40:60	More bubble were found

Table 4.4. Results obtained for leak test

4.4 BIODEGRADABILITY TEST

As we know that, organic matters are easily compostable and degradable. In such a case, the vegetables are all organic and can be easily degraded. Similarly, the peel powder obtained from vegetables is also equally easily degradable. On the other hand, chitin being a natural biopolymer can degrade when exposed to the soil environment for a longer time. The biodegradation rate of the samples increased for all the samples as the biodegradation time and the organic content in the package blended increased. As a result of the performed test, the food package made from the vegetable peel powder and chitin bound by gelatin has better biodegradability due to less plasticity. Refer to table 4.5. Usually, plastics and other inorganic materials, in general, have the least tendency to degrade, so in sequence with that our bio package has the maximum level of biodegradation when in contact with the soil environment.

Sample ratio	Duration of test	biodegradability
R_1 80:20	10 days	Completely biodegradable
R_2 60:40	**10 days**	**Completely biodegradable**
R_3 50:50	10 days	Completely biodegradable
R_4 40:60	10 days	Completely biodegradable

Table 4.5. Biodegradability test results

4.6 pH TEST

Considering the presence of Gallic acid, Citric acid, Glycolic acid, Sulfeunic acid, etc., present in the vegetable peels along with chitin's presence. The pH of sample R_2 60:40 was found to be 6.2, which is almost neutral and least acidic. Refer to table 6. Hence, we have concluded that the acquired pH range is not harmful to any food sample that will be stored inside this prepared packaging.

Sample ratio	pH
R_1 80:20	4.4
R_2 60:40	**6.2**
R_3 50:50	4.9
R_4 40:60	5.8

Table 4.6. pH values obtained for the different samples.

4.7. COLOR CHANGE TEST

The color change test was performed on the various package samples. It was carried by manual observations process. The observed changes and inference was tabulated. There was no color change observed in the samples R_2 60:40, R_3 50:50, R_4 40:60 since the chitin composition was high. Whereas in sample R_1 80:20 the composition of vegetable peel was high which lead to color change.

Sample ratio	Color change (without food sample)
R_1 80:20	Color change observed (dark maroon to pale pink)
R_2 60:40	**No color change**
R_3 50:50	No color change
R_4 40:60	No color change

Table 4.7. Color change test results.

4.8. SHELF LIFE ANALYSIS

The shelf life analysis was conducted by storing food contents into the package. The overall process was carried out for 2 weeks. The changes inferred were tabulated for easy study.

i. **Category I- On the basis of perishability**

Food sample	-	**Mushroom**
Duration of study	-	2 weeks
Changes observed	-	• No colour change in package. • Colour change was observed in mushroom after 8 days (under refrigeration). • Produced pungent odour after 9th day

ii. **Category II – On the basis of semi-perishability**

Food sample	-	**Chips**
Duration of study	-	2 weeks
Changes observed	-	• No colour change in the package. • Odour was produced after 7 to 8 days. • Slight Texture changes was observed.

iii. **Category III – On the basis of non-perishability.**

Food sample	-	**Rava**
Duration of study	-	2 weeks
Changes observed	-	• No colour change in package. • No unpleasant odour was found. • No colour change in the food sample.

V. CONCLLUSION

The development of a sustainable solution for managing vegetable waste by replacing plastics was the overall idea of this research project and has become extremely important in the present scenario too. Therefore, the development of an alternate food package with waste vegetable peels is one of the solutions that could be utilized to support in attaining the social, environmental, and economic benefits from these wastes. The unique biochemical properties of chitin suggest that they could be seen as almost ideal binding agents used in package manufacturing. As the overall aim of the project, the product samples have turned out as desired and with quality standards.

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