Moisture absorption percentage and evaluation of quality changes in extruded snacks during storage for different thickness of foil

Faridul Wahid

Roll No. 0120/03

Registration No. 829

Session: Jan-June, 20

A thesis submitted in the partial fulfillment of the requirements for the degree of Master of Science in Food Chemistry And Quality Assurance

Department of Applied Chemistry And Chemical Technology

Faculty of Food Science and Technology

Chattogram Veterinary and Animal Sciences University

Chattogram-4225, Bangladesh

June 2022

Authorization

By signing this statement, I claim exclusive authorship of the thesis. I provide permission for the Chattogram Veterinary and Animal Sciences University (CVASU) to lend this thesis to other institutions or persons for scholarly research. I further give the CVASU permission to reproduce the thesis in whole or in part, for scholarly research purposes, at the request of other institutions or people, and to reproduce it in any other way, including photocopying.

In accordance with the capabilities of the technology at hand, I, the undersigned and author of this work, certify that the electronic copy of this thesis presented to the CVASU Library is an exact replica of the print thesis submitted.

Faridul Wahid

June, 2022

Moisture absorption percentage and evaluation of quality changes in extruded snacks during storage for different thickness of foil

Faridul Wahid

Roll No. 0120/03

Registration No. 829

Session: Jan-June, 20

This is to certify that we have examined the above Master's thesis and have found that is complete and satisfactory in all respects and that all revisions required by the thesis examination committee have been made

----

(Dr. Shamsul Morshed)

Supervisor

Associate Professor

Department of Applied Chemistry and Chemical Technology

(Dr. Shamsul Morshed)

Chairman of the Examination Committee

Department of Department of Applied Chemistry And Chemical Technology

Faculty of Food Science and Technology

Chattogram Veterinary and Animal Sciences University

Khulshi, Chattogram-4225, Bangladesh

June 2022

PLAGIARISM VERIFICATION

Title of The Thesis: Moisture absorption percentage and evaluation of quality changes in extruded snacks during storage for different thickness of foil

Name of the student: Faridul Wahid

Roll number: 0120/03

Reg. number: 829

Department of Applied Chemistry And Chemical Technology

Faculty of Food Science and Technology

Supervisor: Dr. Shamsul Morshed

For Office use only

This is to report that as per the check …………% of the content thesis is stated to be plagiarized and covered /not covered as per plagiarism policy and institutions issued from CASR, Chattogram Veterinary and Animal Sciences University.

The thesis may / may not be considered for the evaluation

Dr. Shamsul Morshed

Associate Professor

Department of Applied Chemistry and Chemical Technology

DEDICATED TO MY BELOVED FAMILY & TEACHERS

Acknowledgements

First and foremost, I would like to express my sincere gratitude to **"Almighty Allah,"** whose favor has made it possible for me to finish the thesis for the degree of Masters of Science (MS) in Food Chemistry and Quality Assurance.

I would like to express my sincere and sincere gratitude to my supervisor, Dr. Shamsul Morshed, Associate Professor in the Department of Applied Chemistry and Chemical Technology at the Chittagong Veterinary and Animal Sciences University, for his effective guidance throughout my entire study period. He worked through several drafts of my text, offering insightful criticism and difficult questions. My experience was greatly enhanced by his knowledge, useful advice, consistent encouragement, kind demeanor, patient understanding, and constructive criticism.

I want to express my sincere gratitude to the department head and the team members who contributed to this research on behalf of the Abul Khair Consumer Goods Division's Quality Assurance Department, Departments of Applied Food Science and Nutrition, Applied Chemistry and Chemical Technology, Animal Science and Nutrition, Food Processing and Engineering, and CVASU for their generous support and ongoing inspiration in carrying out the research activities in those laboratories precisely.

I must conclude by expressing my sincere appreciation and warm thanks to my devoted family, friends, and well-wishers for their support, cheer, and inspiration throughout the study. I sincerely appreciate my parents' patience, understanding, moral support, compassion, blessings, and unending love for helping me finish my studies.

The Author

June, 2022

Contents	Page No.

List of Table

List of Figure

Abbreviation

MVTR	: Moisture Vapor Transmission Rate
OTR	: Oxyzen Transmission Rate
WVTR	: Water Vapor Transmission Rate
RTE	: Ready -To –Eat
ASTM	: American Standard Testing Method
LDPE	: Low Density Polyethelyne
HDPE	: High Density Polyethelyne
PET	: Polyethylene Terepthalate
MPET	: Metalized Polyethylene Terepthalate
PVC	: Polyvinyl Chloride
BOPP	: Biaxially Oriented Polypropylene
PE	: Polyethylene
PP	: Polypropylene
IMC	: Initial Moisture Content
CMC	: Critical Moisture Content
GSM	: Grams Per Square Inch
QAD	: Quality Assurance Department
RH	: Relative Humidity
TBT	: Technical Barriers to Trade

Abstract

Snack foods today offer a variety of benefits, including being nutritious, delicious, and even functional. When it comes to keeping snacks convenient and fresh, a snack food packaging must really provide. This paper deals with experimental studies on moisture absorption rate of plastic films that are currently being used as primary and secondary packaging materials for snacks food products at different environmental conditions. The analysis was done on four plastic films include PET, MPET, PE bases. The water vapor transmission rates were determined at accelerated conditions of 90% relative humidity and at 38°C temperature as per the ASTM F1249 standard. The rate of moisture absorption increases linearly with time until a certain point, after which it becomes constant. The water vapor transmission rates were found for four different sample (Sample A, Sample B, Sample C, Sample D) 0.4941, 0.4138, 0.3496, 0.4949 respectively. The moisture content was found ranging from 1.57% to 2.58%. Sample B and Sample C which contain extrusion PE showed good result which was 1.58 % and 1.57% respectively. The polyethylene film with extrusion coating had better moisture barrier properties with good mechanical structural integrity and is the most economical. The multi-layered film of 73 µ showed good results with lower MVTR as well as overall acceptability.

Keywords: Extruded Snacks, Flexible Packaging, Water Vapor Transmission Rate Thickness, Foil, Film, Permeability.

Chapter 1: Introduction

The development of the food industry has been significantly influenced by food product packaging. Food can get from the producer to the consumer through a complicated procedure. The purposes of a package include safeguarding, ease of use, communication, and containment of packaged goods in conditions like those encountered during packaging, storage, and distribution. Protective packaging makes it possible for goods to be delivered to consumers and has allowed for the consolidation of production facilities in regions with a high concentration of raw materials, allowing for the exploitation of economies of scale (Biji et al. 2015). Considering one without the other is impossible due to the growing interdependence between the product and its packaging (Meritaine et al. 2018, Majid et al. 2018, Kim and Seo 2018, Yun and Dong 2017).

Food deterioration caused by moisture, oxygen, and to some extent, organic vapor penetration is one of the major issues the food industry deals with. Moisture, filling gas, temperature, light, and pH are some factors that affect the packaged food's ability to deteriorate. The most significant elements impacting the quality preservation of its contents are the moisture content and gas permeability of the food packaging materials (Mo et al. 2014). A better method of food preservation is required since storing food in unsuitable conditions speeds up degradation. These food products' shelf lives are greatly extended and their quality is preserved when they are packaged using the right polymeric material.

The packaging business makes considerable use of materials for packaging such polyethylene, polypropylene, polystyrene, vinyl polymers, etc. Economical factors lead to the implementation of plastic films for food packaging since they dominate alternative packaging materials in terms of their physical, chemical, and mechanical qualities. The moisture that tends to permeate through the film materials is a significant flaw that affects the texture, color, and consequently the sensory quality of the food product. Because these plastic packaging films are so susceptible to and permeable to water vapor, there is an increasing need to identify a method that will work for measuring the rate of water vapor transmission through them (Majid; Ahmad Nayik; Mohammad Dar and Nanda 2018). In areas with high temperatures and humidity, food products have a much shorter shelf life (Abbas et al. 2019). Use of a packing material that can get through this barrier is therefore essential (Wikström et al. 2014). To find the best material for the packaging of food that contains sweetening, coloring, and flavoring chemicals, four sample films were selected, and the total performance of these plastic films was calculated. These example movies were picked because of their popularity and potential for extensive distribution in the present consumer climate. The four films were obtained from commercial sources and are potential candidates for the packaging and food processing industries.

Aim and Objectives:

i. To compare moisture absorption percentage of extruded snacks (Chanachur) for 4 different layer of foil.
ii. To analyze and compare Water Vapor Transmission Rate (WVTR) among the different thickness of foil.
iii. To compare the overall acceptability of the developed product.

Chapter 2: Review of Literature

2.1 Overview of snacks food

Snack foods are typically consumed in between meals for enjoyment and relaxation; they are not typically a part of the main course. Snack foods are highly prone to impulse purchases and have grown in popularity as a result of the following factors:

- a growing urban population
- an increase in nuclear families
- a rise in the number of working women
- media exposure, which stimulates an interest in novel foods, and
- higher disposable incomes

Although manufacturers and consumers classify and view snack food differently from place to region, generally, snack food are a category of savory, crispy goods that are ready to eat and have a shelf life of 2 to 16 weeks at room temperature.

2.2 Description of snacks product

Third-generation snacks or pellets are sometimes known as semi- or half-products because, following extrusion cooking, they are dried to a stable moisture level before being expanded via frying in hot oil, puffing in hot air, or, in the case of newer variations, microwaving and infrared heating. A variety of spices are added to the product after expansion, and it is then packaged and offered for sale as ready-to-eat (RTE) snacks. Additionally, they can be flavor-infused prior to growth and offered as pellets for home preparation (Sevatson and Huber, 2000). The capacity to make a wide range of products is made possible by 3G snacks' stability during storage and high bulk density. The goods can be made with a variety of raw materials and ingredient combinations (Huber and Rokey, 1990). Flours (corn, potato, rice, wheat, oat, etc.), starches (corn, wheat, potato, tapioca), liquid shortenings, and monoglyceride are common basic ingredients. Meat (shrimp, crab, chicken, or beef), vegetable powders or food industry by products (sugar beet pulp, apple pomace, tomato pomace, bran, etc.), milk components (yogurt, cheese, whey), or any other flavor that the client will find appealing can all be added as flavoring or nutritional ingredients (pizza, ham, onion, etc.).

Snack Food Packs on Sale

Unbranded Traditional Food Snacks

Fig: 2.1 Some Unbranded & Branded Snacks products in Bangladesh

2.3 Standard recipes for snacks

A wide range of raw materials can be chosen for snack production. It needs to include a lot of starch in order to enhance the end product's expansion. Less enlarged end product, more crunch and firmer texture are the results of total starch levels less than 60% in a recipe. In Table 1, some common formulations are shown. Numerous aspects of the final product are influenced by starch, including final expansion, flavor, caloric value, resilience, binding, viscosity, hardness, stiffness, crunchiness, and many more. It is crucial to choose the right cereal grains, starches, proteins, and other minor ingredients because of this. For making foams, for instance, potato amylopectin starch is preferable than high amylose potato starch. According to its capability to swell in water, amylopectin is thought to have a superior capacity to store water. When bubbles are injected into a gel made of high amylose potato starch, there is not enough strength to trap the bubbles and form pores (Sjoqvist and Gatenholm, 2007).

Table 2.1.Typical formulas for Snacks

Hard, Crunchy Texture	
92% Ground corn 5% Corn starch 0.5% Monoglyceride 2.5% Liquid shortening	Huber (2001)
94.5% Corn or wheat flour 5% Corn or wheat starch 0.5% Monoglyceride	Moscicki (2011)
Soft, Frothy Texture	
55% Corn starch 30% Wheat starch 14% Tapioca starch 1% Deoiled lecithin	Huber (2001)
56% Corn flour 27.5% Wheat starch 14% Tapioca starch 2.5 Vegetable oil	Moscicki (2011)
7% Wheat flour 9% Rice flour 80% Tapioca flour 13% Vegetable oil 1% Salt	Moscicki (2011)

Different kinds of shortenings, vegetable oils, salts, and emulsifiers are employed to reduce stickiness, control expansion, and import a more homogeneous cellular structure into the finished product. When someone is dying, salt is highly helpful in facilitating moisture migration. After expansion, baking soda imparts unique flavor and textural qualities. If monoglycerides are administered in amounts of 0.5% or more, they may inhibit growth. Even while the extruded materials' microwave-heated foaming behavior was adversely affected by the inclusion of additives like glycerol and polyvinyl alcohol during extrusion, their dielectric loss factors were still larger than those of the starch-based materials without additives (Peng et al., 2013). A variety of proteins and protein enrichments, including meat (fresh shrimp, chicken, beef, etc.), dairy products (milk solids, cheese, yogurt), and legume proteins, can be added to 3G snacks (soya, bean, pea). They can be included up to 30 to 35 percent and still produce a high-quality result (Riaz, 2006). Nonfood-grade whole potato flour has good potential for application in the creation of expanded pellets with tolerable functional qualities, according to research by Bastos-Cardoso et al. (2007). With high-quality physicochemical properties and potential health benefits derived from nutraceutical qualities, blue corn and orange vesicle flour can also be utilized to make 3G snacks (Camacho Hernandez et al., 2014; Navarro-Cortez et al., 2014; Tovar-Jiménez et al., 2015).

2.4 Expansion by deep-fat frying

Deep-fat frying is a unit operation that involves cooking and frying food while it is submerged in heated oil that has a temperature of between 150 and 180 °C. This allows for quick heat transmission and a short cooking time (30-40 seconds). Short cooking periods with distinctive qualities including color, taste, flavor, crust, and texture are its aim. However, because the internal temperature of the fried food product does not exceed 100 °C, there is little water-soluble food component leaching. Although several strategies have been investigated to lower the oil level in fried food products, the majority of fried foods still include sizable amounts of oil. Three theories—water replacement, cooling-phase effect, and surface-active agents—are put out to explain the phenomenon of oil absorption, but none of them can fully account for it (Dana and Sam Saguy, 2006; Huber and Rokey, 1990). The major oil absorption process is described by relatively big voids in the fried meal by the water-replacement mechanism. When the food is taken out of the fryer, the majority of the oil is absorbed. Viscosity of the oil, as well as the microstructure and surface properties of the product, all have a significant impact on how much oil is absorbed. The increased oil uptake during extended frying can only be partially explained by the production of surface-active agents. Increased oil viscosity brought on by polymerization processes occurring in the deteriorating oil during prolonged frying is likely connected to higher oil absorption (Dana and Sam Saguy, 2006). Several essential elements for the best possible expansion are present during the expansion process. The idea that expansion is best at the moisture content where the glass transition and boiling line overlap was examined by Van der Sman and Broeze (2014a). They created a multiscale simulation model with just a few fitting parameters after successfully confirming this notion. Later, they investigated how salt affected the growth of starchy snacks during frying using that model. They have discovered that the optimal expansion of salty snacks takes place under the identical circumstances as those of salt less snacks. Through a shift in the glass transition, salt is demonstrated to affect both the boiling line and the critical viscosity line. Compared to unsalted snacks, salty snacks should have a reduced moisture level (Van Der Sman and Broeze, 2014b). The most crucial qualities of fried foods are texture and flavor. Before frying, the food's properties, including its water content, size, the types and amounts of protein and starch, the composition of the coating materials, and any additions, are crucial aspects that affect the final product's texture. It's also important to take into account processing factors including cooling conditions, moisture management, frying duration and temperature, etc (Shieh et al., 2004). Van Laarhoven and Staal (1991) investigated the rheology of the paste created during the extrusion of gelatin to create 3G snacks. They also looked at how the product's sensory qualities were affected by the process circumstances. The conclusion is that low temperatures and high moisture contents result in a soft texture and a smooth surface, whereas high temperatures and low moisture contents produce a hard and crispy texture. Bahramparvar et al. (2012) looked into the effects of various periods and temperatures on the sensory and textural characteristics of fried snacks. They came to the conclusion that the texture and sensory qualities of pellet snacks were significantly influenced by the deep-fat frying settings. Changes in frying temperature (150, 170, and 190 °C) and duration (0.5, 1.5, 2.5, 3.5, and 4.5 min) have a direct impact on how crispy the food is. Customers should be polled about the ideal prototype during the development of a new kind of product in order to meet their expectations and needs. In order to identify the ideal formulation of ingredients and extrusion conditions for the production of snack prototypes and to validate the predictive models used for the optimization process, Choi et al. (2007) evaluated peanut-based, indirectly puffed extruded snack products using a consumer affective test. The most common raw materials used to make extruded snacks are cereal and starch.

2.5 Extrusion of Snacks products

The majority of the larger snacks currently sold on the market are made primarily through extrusion and puffing. Extrusion has transformed a variety of conventional snack-making processes and made it feasible to design brand-new snacks.

In comparison to conventional food unit operations, extrusion offers a number of advantages, including less time, energy, and cost inputs and greater manufacturing process flexibility. A wide variety of unique products can be produced by changing the extruder's minor components, operating conditions, and/or ingredients. An extruder can be used for a variety of processes, including feeding, heating, conveying, mixing, kneading, compressing, shearing, cooking, and shaping (forming).

A compressed, heated, and sheared mixture of ingredients emerges from an extender's die as a snack product. Instantaneously evaporating moisture causes the mixture to puff and expand. The configuration of the die and the cutting components dictates the size and shape of the finished product. Extrudates that have been shaped are dried or baked before being flavored or seasoned with oils (Huber and Rokey, 1990; Matz, 1993). The most important parameters to take into account are the extrusion temperature, screw speed, feed rate, barrel/screw designs (configuration), extrusion rate (residence time), and feed composition, including moisture, sugar, salt, and fat content.

The expansion of expanded snacks controls how crisp they become. More expansion is anticipated to come from a greater extrusion pressure and a higher starch concentration in the extruded materials (increased crispiness). Fat typically prevents expansion. Salt encourages expansion, creating a delicate texture. Typically, emulsifiers weaken the structure of starch, which results in less expansion. Extruded snack foods typically have a moisture content of between 8% and 10% (wet basis).

The extruded products are subsequently dried or fried to reduce the moisture content to 1-2 percent in order to obtain the required crispness (Robertson, 2006). Co extrusion has been used to manufacture snacks that typically feature an extrusion-cooked outer shell with a pumpable (but not free-flowing) filling (Huber and Rokey, 1990). The extrusion-cooked portion of the snack will flow parallel to the extruder barrel's passage through the die. The filler is pumped into the die and flows inside the shell extrudate.

2.6 Packaging Materials of Food Products

Based on fundamental criteria that reflect customer demands, food packaging is improved (Market Publishers Report Database ; 2012). In addition to self-service shops, technology that permits packing forms and the distribution of mass packaging materials contributed to the rapid growth of packaging. In today's industrialized nations, factories not only produce items but also, in particular, supply the market with ready-to-eat food products. The packaging of the products is influenced by consumer preferences. It is well known that customers give the service sector a larger share of their spending the greater their quality of life. According to Çakıcı, L. (1973), packing becomes more significant as living standards grow. Nowadays, it is growing harder to distinguish between items and influence consumers' purchase decisions due to the shrinking differences between industrially produced products and the rising diversity of products. With increased focus on consumer satisfaction, health conditions, and required consumer rights protection, packaging for industrial items has become more crucial (Dilber, F., Dilber, A., & Karakaya, M. 2012). Production managers attempt to differentiate the product's packaging and give it an identity by understanding the importance of packaging involved (Underwood, R. 2003). In addition to being a marketing tool, packaging extends the life of the product (Odabas, Y. and Oyman, 2005).

Dobrucka et al. (2015) assert that packaging can significantly improve food security, enhance consumer satisfaction, and enhance quality of life for consumers. Glass, metals, plastics, and paper are just a few of the diverse materials used to make food packaging, each of which has a different performance profile. Since they have already been extensively documented elsewhere, the characteristics of these different materials won't be explained in depth here (Lee et al., 2008; Piringer and Baner, 2008; Robertson, 2006; Yam, 2009).

2.7 Packaging Requirements of Ready-to-Eat snack extruded (RTE) Foods

Any food item that doesn't need the consumer to go through any laborious processing steps before it is fit for eating may be referred to as "ready-to-eat." As soon as the package is opened, it is in a state that is tasty and appetizing and is ready to consume. Basic specifications for the packaging of extruded snacks include:

Grease proof

Rancidity

Loss of crispiness

Machinability

Physical strength

Printability

Seal integrity

The following are some crucial packaging factors that affect the selection criterion for choosing packaging materials.

2.7.1 Greaseproofness

The presence of fat shows that the main requirement for snack food packaging is greaseproof packaging. This standard is crucial to meet in order to reduce rancidity as well as to prevent ugly package discolouration, printing blurring, and actual oil seepage that gives the package a greasy feel.

2.7.2 Rancidity

Due to the product's high fat content, it is also necessary to prevent it from coming into contact with airborne oxygen. It is better to use a packing material with a low oxygen permeability to prevent fat from oxidizing and going rancid.

2.7.3 Loss of Crispness

The crispness of snacks is one of their distinguishing qualities, and it is achieved during manufacture by utilizing a drying procedure, such as roasting, baking, or frying to reduce the moisture content. How long a product retains its ideal texture directly depends on how much moisture it contains (crispness). The snack is hygroscopic and has a very low moisture content, thus any increase could cause the crispness to decrease. Additional moisture also hastens other metabolic changes including oxidative rancidity. Low water vapor permeability of the packaging becomes another essential requirement as a result.

Dry food systems may not maintain the proper crispness after opening the box or while being stored. Consumers commonly reject snack foods because of loss of crispness brought on by moisture uptake (Robertson, 2006). As the law grows due to moisture absorption, puffed rice cakes were found to lose their crispness and become tough; rice cakes with an aw between 0.2 and 0.4 have the best crispness and low hardness (Hsieh et al., 1990).

According to reports, potato chips and corn chips have a critical aw of 0.4; at aw of 0.5, potato chips become organoleptically undesirable (Katz and Labuza, 1981; Robertson, 2006). Extruded rice snacks and puffed corn curl have been observed to have critical aw values of 0.36 and 0.43, respectively (Chauhan and Bains, 1990; Katz and Labuza, 1981).

To predict product shelf-life and package performance with regard to water vapor transport, the following information is required:

- The moisture isotherm data
- The WVTR of the film/laminate
- The storage circumstances

2.7.4 Machinability

Recently, several snacks are no longer manually filled into prepared bags; instead, they are being packed using automatic form-fill machines that may operate at fairly rapid speeds. Therefore, packaging materials must be able to operate effectively and constantly on these equipment.

2.7.5 Physical Strength

An inert gas like nitrogen may be substituted for oxygen inside a packaging where a longer shelf life is required due to the high fat content of snack food products and the accompanying problem of rancidity. The packaging material must be robust enough to endure the vacuumizing and gas cleansing operations. There are differing opinions on the matter of the material's rigidity. The ability of the package to stand upright on the shelf is desirable, yet extreme stiffness causes machinability issues.

2.7.6 Printability

A good printing surface should be provided by the package material. In order to compete in the market, numerous manufacturers of comparable snack foods must use eye-catching printing.

2.7.7 Seal Integrity

To ensure protection against climatic conditions and a long shelf life, the seal integrity of the pack must be robust enough to prevent leakage and/or prevent entry of the air or moisture via the seal areas. The aforementioned needs for snack food packaging are considerably satisfied by plastics in a number of forms, including flexible pouches of films and laminates, plastic containers and trays, and as a component in composite packs.

2.8 Flexible Packaging for Snacks Food

Flexible packaging has long been the area of the packaging business that is expanding the fastest (Selke & Culter, 2016). The food industry has historically been the main end-user of flexible packaging, accounting for 70% of the worldwide flexible packaging market in 2020. (Flexible Packaging Market, 2021). In 2021, the market for flexible packaging is anticipated to reach 31.5 million tonnes, with an average annual growth rate of 3.3 percent (Smithers, 2021). Flexible packaging includes foil wrappers and bags constructed of various materials that, when filled and sealed, take on a flexible shape (Ebnesajjad, 2013). Particularly polymer mono-materials and polymer-based multilayer materials, out of all flexible packaging materials, are widely utilized in the packaging industry and have a wide range of applications in food packaging (Palic et al., 2019; Zolek-Tryznowska et al., 2020). The cause of this is having good qualities like low cost, low weight, tolerability with content (especially foodstuff), an appropriate barrier, mechanical and optical properties, as well as suitability for processing by printing and packaging machines (Peri-Mareti et al., 2014; ShaguftaIshteyaq et al., 2019).

Tensile strength, elongation, and permeability are among the essential performance requirements for flexible packaging foils and have a significant role in the general characteristics of printed packaging goods made of polymeric materials (Ebnesajjad, 2013).

Low permeability by light, oxygen, moisture, CO2, fragrance, or fat are barrier qualities of polymers (Desnica et al., 2015). These qualities are crucial because contact between food products and air gases can result in biochemical or physical responses that can lower food quality (Fotie et al., 2017). Varied materials for packaging have different gas-barrier qualities. Porosity or permeability is a characteristic of packaging materials. Paper with porosity allows for the diffusion of gases occurs physically as a result of molecules moving between the material's interpores.

A physical-chemical mechanism known as permeability allows for the passage of gas molecules under the effect of chemical affinity or solubility. The molecules first absorb on the material's surface, then diffuse through the foil in the direction of the concentration gradient, and finally desorbs on the other side.

The packaging must be strong enough to survive processes involving additional food manufacturing, handling, transit, and distribution (Balaban-Durdev, 2006; Marangoni et al., 2020; Izdebska et al., 2015). It has been discovered in earlier studies by Hertlein (1997), Rubino et al. (2001), Mrkić et al. (2007) and Siracusa (2012) that production, handling, packaging, and printing procedures can have an impact on various aspects of flexible packaging materials, particularly barrier qualities. For instance, absorbing liquids or vapours from the environment can result in a loss of mechanical characteristics (Siracusa, 2012; Sangroniz et al., 2019). It has been discovered that the mechanical stress of the folds alters the barrier's characteristics, both for the monofilm and laminate types. In general, the film with a metalized layer in the structure showed the greatest change in gas permeability with a higher stress cycle (Hertlein, 1997; Mrkić et al., 2007; Siracusa, 2012).

Today, the great majority of snacks are contained in flexible bags. A variety of flexible materials are used for snack food in the Bangladeshi market, depending on the product and the market niche. Wafers and other common, inexpensive snack foods come with or without branding. For a shorter shelf life, unbranded snacks are packaged in simple low density polyethylene (LDPE) and polypropylene (PP) pouches. Branded nuts and snacks are packaged in laminated structures. Typical constructions include:

- BOPP / LDPE
- BOPP / Polyester/ LDPE
- Metalized Polyester / LDPE
- BOPP / Metalized Polyester / LDPE
- Polyester / LDPE
- Polyester / Aluminum foil / LDPE
- (LLDPE or cast PP might potentially be used as the sealing layer.) The standard packaging designs for crisps and other related snack foods in the world markets are:
- PVDC coated glassine
- PVDC coated glassine / OPP
- Sulfite Paper / OPP
- Co-extruded HDPE
- Orientated Polypropylene Films (coated, uncoated, co-extruded)
- LDPE / EVA films
- HDPE / EVA seal layer
- OPP / PE / PVDC coated OPP
- OPP / PE / metalized heat sealable OPP

- PVDC coated PET
- OPP / PVDC / OPP Lamination

2.9 Single and multi-layer materials Packaging

Some flexible packaging is made from a single layer material while, in other cases, multi-layer materials are required to provide the appropriate barrier and protection. Each layer performs a different function in protecting and preserving like: product protection, contamination prevention, extended freshness, puncture, burst and tear resistance, seal and tensile strength.

2.10 Rationale for multilayer flexible packaging

Materials used in packaging can be broadly divided into monolayer and multilayer materials. Films, foils, and paper are examples of monolayered materials. Coated substrates, coextrusions, and laminates are examples of multilayers. A number of both traditional and novel materials are considered while deciding on the material for a certain product. It's frequently crucial to use a multilayer package when no one material can offer all the desired qualities required to enclose and protect a product. The existence of the other material can compensate for any drawbacks or deficiencies of the first substance. A multilayer structure's layers can each perform one or more packaging-related tasks. Strength, printability, barrier, and heat sealability are a few of the key roles.

Multiple processes can be used to create multilayer packaging materials (Joseph F. Hanlon et al., 1998). Co-extrusion, coatings, and lamination are major categories into which these techniques might be divided. These procedures are commonly utilized in the flexible packaging sector. After taking into account various coating and laminating materials, layer thickness requirements, the structure's formability both before and after joining, specific property requirements like a barrier to moisture and gases, sealing capability requirements, printing requirements, and other factors, the choice of coating, laminating, or co-extruding is made (William E. Brown et al., 1992).

For instance, paper can be laminated or coated with plastic sheets to become a gas and moisture resistant material while preserving its stiffness and printability. Using combinations of materials rather than monolayered structures can also be more cost-effective (William E. Brown et al., 1992).

2.11 Multilayer Types

2.11.1 Co-extrusion

Extrusion dies for cast and blown film can be made to accept feed from several extruders, resulting in co-extrusion of numerous layers. One benefit of coextrusion is making it possible to sandwich recycled material between layers of virgin polymer, which might be important from an ecological and financial standpoint (Walter Soroka, 1999)

2.11.2 Coatings

The process of putting one or more layers of a fluid or melt to another material, improving the performance of the coated material, is known as coating (William E. Brown et al., 1992). Enhancing the qualities of a single packaging material is a popular practice. It can be used to provide heat sealability, enhance barrier characteristics, or safeguard a film surface. The provision of waterproofing, coloring, and preservation functions, or a mix of roles, are some additional advantages of coating.

2.11.3 Adhesion and Adhesives

Adhesion is the process by which two dissimilar bodies (adherents or substrates) are kept together by intermolecular forces, frequently with the aid of a third substance (referred to as an adhesive). By heating the substrates and pushing them together, similar to how thermoplastic materials are heat sealed, the adhesive action can be produced (Susan E. M. Selke et al., 2004)

2.11.4 Surface treatments

Surface treatment may frequently be required in order to make the adhesives, coatings, and inks adhere to or "wet" the surface of the film. When the substrate's critical surface tension is higher than the wetting liquid's surface tension, wettability is obtained (Joseph F. Hanlon et al., 1998, Walter Soroka, 1999). The propensity of a liquid to reduce its surface area is known as surface tension.

2.11.5 Lamination

Lamination is the process of joining two or more materials typically films and foils together. In a lamination line, these materials are referred to as webs. A long continuous material might be referred to as a web of material. The advantages of these webs can be combined with one another and their disadvantages can be eliminated by lamination. The adhesive coating is heated, dried, and pressure is applied to establish the bonding (William E. Brown et al., 1992).

2.12 Barrier properties

The materials used for flexible packaging may need to protect the product from exterior effects, such as atmospheric contaminants, light, UV rays, gas, oxygen, moisture, puncturing, or tearing, or from internal influences, such as moisture, oils or greases, chemicals, detergents, etc. It is crucial that the elements cannot move inside or outside of the packaging.

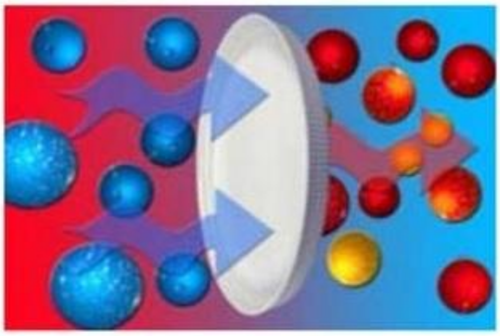

Fig: 2.2 Moisture barrier properties of flexible packaging

High Moisture Barrier Flexible Packaging

Flexible packaging materials have a predetermined moisture vapor transmission rate (MVTR). Foil, HDPE, and PVDC are examples of materials with good moisture-barrier abilities.

2.13 Water Vapor Transmission Rate (WVTR)

The term "water vapor transmission rate" (WVTR), sometimes known as "moisture vapor transfer rate" (MVTR), is the accepted measure of the ease with which moisture can penetrate a packaging film. Flair gives WVTR readings for 38 °C and 98 %

relative humidity given as g/m2 and g/100in2 (per ASTM F1249). Increasing WVTR values indicate increased permeability and decreased capacity to keep moist and dry items moist, respectively.

The following factors affect WVTR values:

Thickness

Resin Composition

Molecular weight distribution

Crystallinity/density

Chain-length and chain-length distribution

Chain orientation

Polymer blends

Additives

Coatings – *PVdC, metalizing*

Processing Parameters – BUR, frost-line height, die gap

To provide the best barrier properties for a certain product's demands, MVTR and oxygen transmission rate (OTR) are frequently balanced when choosing a packaging film.

Film Type	**WVTR @ 100°F (38°C), 90% RH for 1 mil film**	
	(g/100 in²/24 hr)	**(g/m²/24 hr)**
Biax OPP	0.25 - 0.40	3.9 - 6.2
HPDE (high density polyethylene)	0.3 - 0.5	4.7 - 7.8
Cast PP	0.6 - 0.7	9.3 – 11
Biax PET (oriented polyester)	1.0 - 1.3	16 – 20
LDPE (low density polyethylene)	1.0 - 1.5	16 – 23
EVOH* (ethylene vinyl alcohol)	1.4 - 8.0	22 – 124

Table 2.2: Normalized WVTR values for common films

High Oxygen Barrier Flexible Packaging

Several items, including many in the medical and pharmaceutical, food, or personal care markets, need packaging with low or almost nonexistent oxygen transmission rates (OTR). For instance, many foods require a container design that completely excludes oxygen to preserve it and increase shelf life. Without a strong oxygen barrier, the product's color, flavor, aroma, and overall quality may vary. The features of materials used in flexible packaging with regard to their oxygen barrier capabilities vary substantially. An oxygen transmission rate (OTR) is a measurement of how much oxygen permeates a given material over the course of a day.

Table: 2.3 Permeability of various popular plastic packing sheets to oxygen and water vapor.

Plastic	Oxygen permeability (OP)			Water vapor permeability (WVP)		
	OP x 10^7 (mL m m^{-2} day^{-1} Pa^{-1})	T (C)	RH (%)	WVP x 10^{14} (gm m^{-2} s^{-1} Pa^{-1})	T (C)	RH (%)
LDPE	44.756	25	50	6.673–8.704	38	100
HDPE	7.127	25	50	1.741–3.482	38	90
PP	4.936-9.869	23	50	2.321–4.642	23	85
PET	0.098–0.494	23	50	5.803–22.921	23	85
PVC	0.198–0.790	23	50	18.279	38	90

Chapter 3: Materials and Methods

3.1 Study Area

The experiment was conducted in the laboratory of the department of Applied Chemistry and Chemical Technology and Quality Assurance Department (Packaging), Abul Khair Consumers Goods Division, Chattogram.

3.2 Study Duration

The experiment was carried out from December 21, 2022, to May 20, 2022, over a six-month period.

3.3 Collection of Sample

Samples of foil of different thicknesses and composition were obtained from Arbab Polypack Limited Dhaka. Extruded Snacks (Chanachur) were collected from snacks department of Abul khair Consumers Goods Division. Other relevant resources required for the experiment were collected from the laboratory of Quality Assurance Department of Abul khair Consumers Goods Division.

3.4 Extruded Snacks (Chanachur) Preparation

1.	Receiving of RM for production	Receiving Raw Materials from store as per recipe of different types of frying ingredients, seasoning and others granular items.
2.	Beson Making	Beson prepared from raw peas by grinding machine.
3.	Sieving	Beson are passed through the sifter to eliminate physical hazard.
4.	Dough Preparation	Required amount of treated water and Palm oil is poured into the brine solution preparation tank. Raw materials which are weighed for dough preparation are poured into the tank and stirred with motor driven impeller for about predetermined time period (8-10 mins).
5.	Extruding	Extrusion of dough into the fryer with different shape (Ghatia, Papari, Bundia, Semai etc) through an extruder machine
6.	Frying	Frying extruded dough (Ghatia , Papri, Bundia, Semai etc) with palm oil through a fryer with the temperature range 180-200°C . Peanut, Rice Flakes, Dal (Peas) also fried with palm oil through a

<table>
<tr><td></td><td></td><td>fryer with the temperature range 180-200°C.</td></tr>
<tr><td>7.</td><td>Cooling</td><td>Cooling all the Frying ingredients till ambient temperature</td></tr>
<tr><td>8.</td><td>Seasoning preparation</td><td>Seasoning prepared with different types of spice (Chilli, Turmeric, Clove, Cardamom, Salt etc.) as per standard recipe .</td></tr>
<tr><td>9.</td><td>Frying ingredients Mixed with seasoning</td><td>All of the Frying ingredients mixed with seasoning for 6-8 mins with a tambular mixer machine. The moisture content of mixing extruded snacks (Chanachur) will be 1-1.5 %.</td></tr>
<tr><td>10.</td><td>Filling & Sealing</td><td>Chanachur are packed into pillow type pouch (with various thickness and composition of foil) by packaging machine as per defined weight at specified moisture and temperature.
<table>
<tr><th colspan="2">Sealing Temperature, ^{o}C</th></tr>
<tr><th>Horizontal Sealing</th><th>Vertical Sealing</th></tr>
<tr><td>180±5</td><td>170±5</td></tr>
</table>
</td></tr>
</table>

3.5 Flexible Packaging Material Product Description:

Machinery and equipment selected for this project to manufacture various types of Flexible printing & packaging items as listed below:

- 3 Layer wrapper – PET+MPET+LLDPE
- 4 Layer wrapper – PET+PE+MPET/Alu Foil+LLDP

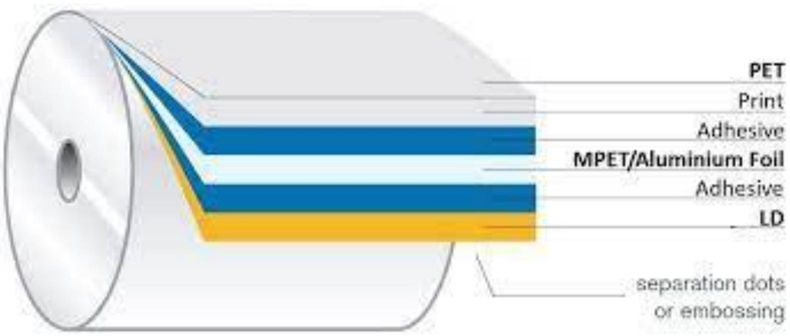

Fig: 3.1 Different Layer of Laminated foil

3.5.1 Manufacturing Process:

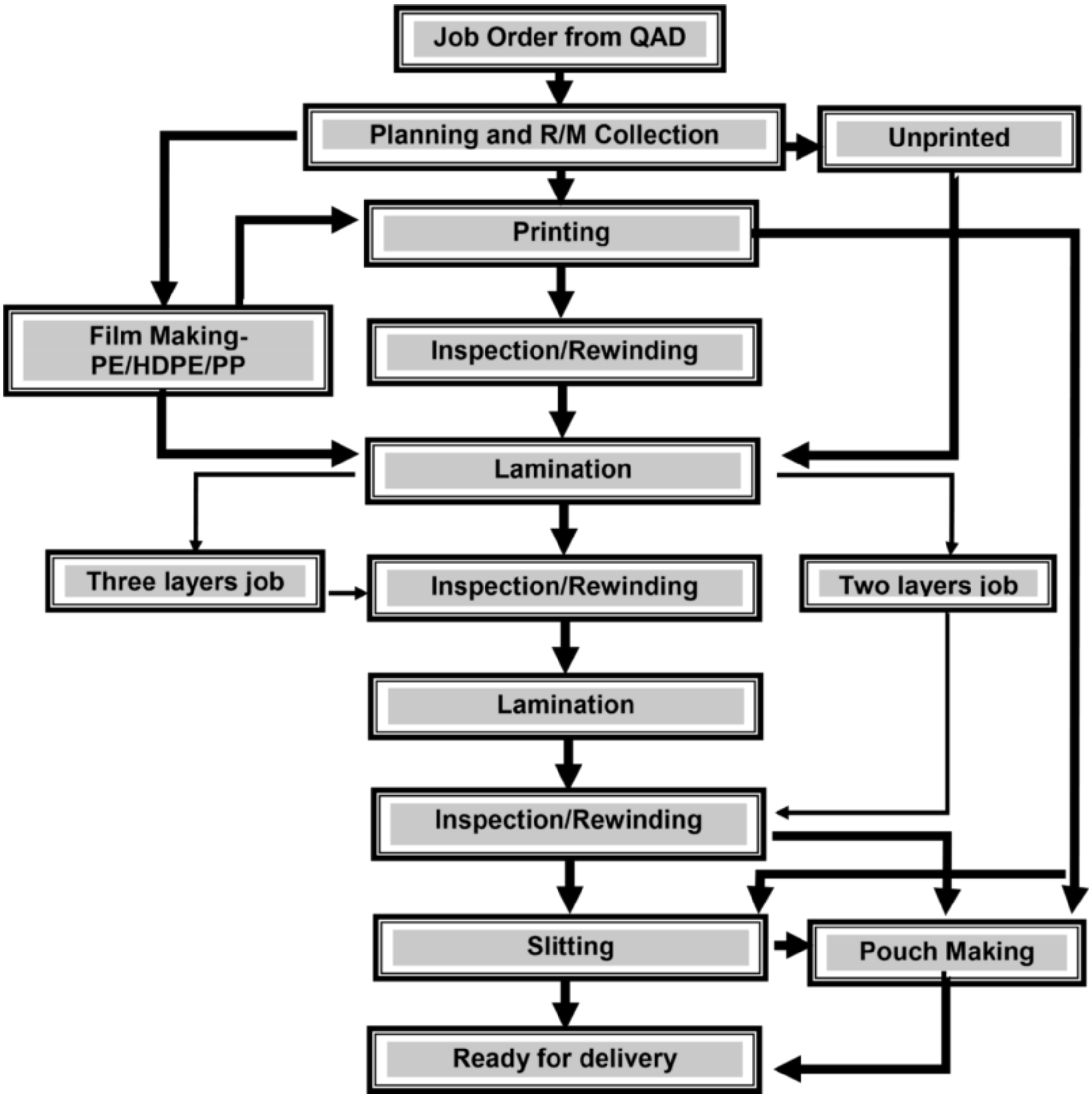

Fig: 3.2 Manufacturing process of Laminated Foil

3.5.2 Specifications

Foods Packaging Material

Product type Packaging films & Pouches

Material Laminated layer or Multi-layers films

Printing Gravure printing (up to 9 colors)

Film type In Roll Form For FFS Machine

Pouch Type Small Sachet

Application Snacks Foods

Type Supply in Printed

Features

- High Oxygen & Moisture Barrier
- Excellent Seal Through Contamination & Heal Seal Strength
- Pack Size From 1 Kg to 50 Kgs
- Food Grade Inks
- Nitrogen Flushing for Snack Foods Laminate

Sample A

Composition of Foil:

4 Layer : 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 20µ PE = 58µ (±5µ)

Sealing Strength: 65.62 Newton Force

Bursting: 130 kpa

Sample B

Composition of Foil:

4 Layer : 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 30µ PE = 68µ (±5µ)

Sealing Strength: 70.12 Newton Force

Bursting: 155 kpa

Sample C

Composition of Foil:

4 Layer : 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 35µ PE = 73µ (±5µ)

Sealing Strength: 80.10 Newton Force

Bursting: 165 kpa

Sample D

Composition of Foil:

3 Layer : 12µ PET + 2µ Ink + 12µ MPET + 2µ Adhesive + 43µ PE = 73µ (±5µ)

Sealing Strength: 90.35 Newton Force

Bursting: 175 kpa

3.6 Moisture Transmittance Tester

Water Vapour transmittance Tester is designed manufactured and implemented according to ASTM F1249 (Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor).

The process for calculating the rate of water vapor transmission through flexible barrier materials is covered by this test method. The technique can be used with single- or multilayered synthetic or natural polymers and foils up to 3 mm (0.1 in) in thickness, including coated materials. It allows for the calculation of (1) the water vapor transmission rate (WVTR), (2) the film's water vapor permeability, and (3) the water vapor permeability coefficient for homogeneous materials.

This standard does not claim to resolve all, or even some, safety issues connected to its use. The user of this standard shall adopt adequate safety, health, and environmental practices and shall prior to use determine the application of any regulatory constraints.

This international standard was created in accordance with the universally acknowledged standardization principles outlined in the World Trade Organization Technical Barriers to Trade (TBT) Committee's Decision on Principles for the Development of International Standards, Guides, and Recommendations.

It is a high precision experimental testing equipment integrating mechanical, electrical and software. Suitable for water vapor barrier test of plastic film , composite film, sheet, metal foil and plastic rubber, paper and other materials of bags, cans, boxes and others packaging containers.

Fig: 3.3 Moisture Transmittence Tester

Working Principle: Water vapor transmittance tester adopts infrared method principle. It will deal with good sample in advance and fixed in the middle of the test chamber, the test is divided into upper and lower two cavity, relatively stable humidity of nitrogen on the film of cavity flows, dry nitrogen gas flow in the inferior vena, due to the presence of moisture gradient, water vapor from the humidity chamber through the membrane diffusion to low humidity chamber, through the sample of the water vapor is the flow of dry nitrogen to use infrared sensor , through the sensor output signal parameters such as water vapor transmittance of the sample drawn.

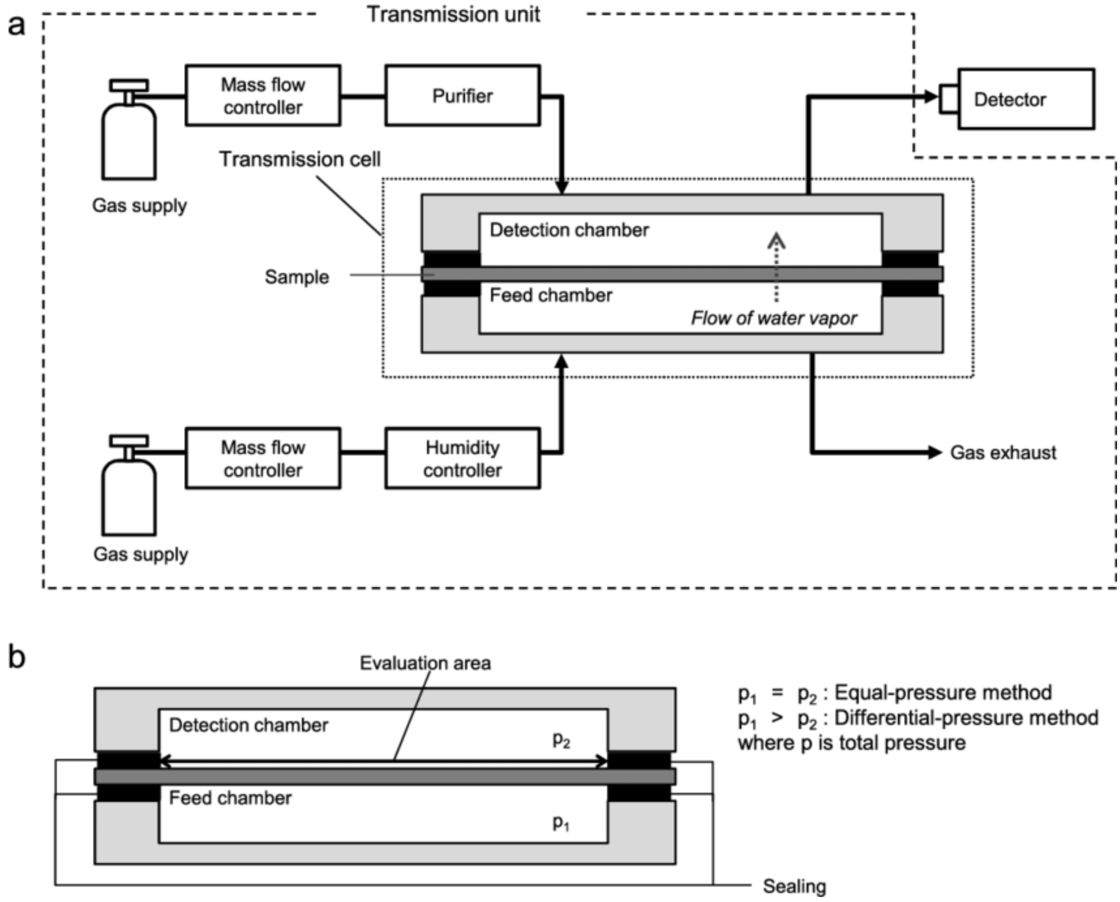

Fig: 3.4 (a) A typical WVTR measurement system's schematic. An illustration of a carrier gas system is shown in the image. There are dotted lines all around the transmission component. (b) A transmission cell's schematic. With the aid of sealing materials, the sample is mounted in the transmission cell. Additionally, the evaluation area is given. In general, the systems can be divided into two categories: equal-pressure methods and differential-pressure methods.

3.7 Test Operations

3.7.1. Requirements

1) Ensure that the laboratory environment temperature is 23°C to prevent excessive concentration of laboratory personnel. (Ambient has asignificant influence on experimental results. A temperature shift of 1° C typically results in a deviation of 6-7%.

2) Ensure that nitrogen is at least 99.9999% pure.

3) Open the cylinder valve after closing the pressure releif valve switch and check the valve on the pressure gauge near the cylinder end. Make sure it is above 1 Mpa and replace the gas when it is close to 1 Mpa.

3.7.2 Preparations

1) Connect the nitrogen cylinder pressure reducing valve to the steel pipe and use N before connecting the steel pipe to the instrument. Flush and connect the other end separately to the nitrogen inlet on the water vapor transmittance meter. Tighten it with a wrench, then open the valve on the cylinder (check that the pressure reducing valve is loose and closed before opening the cylinder), then the turn the pressure reducing valve clockwise to open and adjust the pressure of the low-pressure gauge to 0.1 mpa. Dip a brush with foam water on the joint of each connector and observe whether bubbles overflow. If bubbles overflow is found, tighten the joint at the overflow.

2) Close the pressure reducing valve and record the value of the low pressure gauge at that time (such as 0.1 mpa). 10 minutes later observe whether the value of the low pressure gauge decrease. If does check repeatedly according to the above method to ensure the tightness of the connection between the cylinder and the instrument.

3) Check aluminum foil sealing: first use aluminum foil as baseline, record the data, and then use high barrier aluminum foil test, the comparison data is close, the sealing is good.

3.7.3 Specifications and requirements of samples

Materials:

Plastic film (thickness not greater than 2 mm)

Bottle (Not more than 1 L, diameter no more than 10 cm, height no more than 20 cm,

Bags (Not larger than 20 cm × 30 cm)

Status:

The test sample must be complete and uniform, without obvious wrinkles, no pollution, no pinhole trachoma, etc.

The penetration direction of the sample should be clear when testing.

3.7.4 Film sample cutting process

1. Place a clean and pollution-free test sample on a cutting table.

2. Use a sample cutter to take appropriate sample.

How to use the sampler: Place the sample flat on the rubber pad, gently place the sampler, pull out the locator pin and press the sampler handle to rotate at least 45 degree clocwise to complete the sampling. After sampling is complete , adjust the locating pin to return to the initial position.

3. Ensure that the sample surface is free from wrinkles, creases, pinholes and contamination. It is best to put the sample into a drying dish with descicant for sample state adjustment, and time is about 24h.

3.7.5 Film release process

1) Open the upper cavity cover of the test chamber. Use cotton paper to clean the residues in the upper and lower cavities (note: when lifting the upper cover, please note that there are O-rings in the holes of the two upper cavities and the air nozzle of the lower cavity and do not fall off. If there are falls off, please install the sealing ring.

2) Squeeze about 1 mm of sealing grease onto your fingers, smear evenly along the O-ring clockwise, apply a thin layer. Then the contact surface of the lower cavity and membrane is coated with sealing fat, evenly coated in the same direction, according to the thickness of the membrane determines the amount of sealing fat, thick membrane increase the amount of sealing fat, thin membrane reduces the amount of sealing fat.

3) Then hold the test film with your right hand and test face up. The lower part of the membrane is gently pasted to the sealing grese of the lower cavity. Position the sample gently (note: improper placement of the sample or moving the sample may affect the test results).

If it is found that the film is not flat, the contact surface between the film and the cavity can be touched outward gently with the center of the circle until it is flat. Then gently slide clockwise along the contact surface between the membrane and the cavity with your finger. Drive out the bubbles in the contact surface.

4) Cover the upper cavity cover, both hands hold the two knobs on the two air nozzle protrudes from the lower cavity, slowly put down, first gently observeparallel and then tighten. At the same time, rotate the knob tightly with both hands, and then rotate ¼ turn with a special spanner , and cover the thermal insulation cover. (Note: there will be air leakage if the upper and lower cavities are not balanced.

3.8 Film routine test

3.8.1 Experimental procedure

1. Connect the gas cylinder and the instrument “nitrogen inlet” gas path to adjust the pressure of the reducing valve between 0.1-0.2mpa (no air leakage)

2. Open the instrument switch. After entering the test interface, open the test software and click communication –connect (if the data change, the communication is normal).

3. Click ‘Temperature Control” to start temperature control (set the temperature to 38 degrees, and compensate according to the actual temperature control).

4. Unscrew the test chamber cover with a wrench, load the sample and tighten the chamber cover (the sample has no pinhole wrinkle stains).

5. Click "Test" on the software interface, and the box for saving data in cavities A, B, and C are displayed. Fill the boxes according to the actual situation and click "Save".

6. In the "bypass A" stage, the upper cavity is detected to see if there is air out (if there is air out, it means normal)

7. The test can be stopped after the transmission curve is stable (the curve within a certain range within 5 hours or so).

8. Click the test button to start testing. The instrument is carried out automatically according to the sequence of bypass flushing and measurement.

9. The water vapor concentration value will change with time from large to small and finally stabilize, stable for four hours, generally about 24 hours. In this case "Current Curve" should be selected as water vapor transmittance curve.

10. After the water vapor transmittance curve is stable, click "Stop Test".

11. Export test report as required.

3.9 Moisture content

Principle: In the production and testing of foods, moisture determination is one of the most significant and frequently utilized metrics. The moisture content is directly important economically to both the processor and the consumer since the amount of dry matter in a portion of food is inversely related to the amount of moisture it contains. However, the impact of moisture on food quality and stability is considerably more significant. Moisture content was determined by using the standard procedure of the Association of Official Analytical Chemists (AOAC, 2016).

3.10 Cost analysis

Cost of the foil made from different composition were calculated from the overall ingredients cost which were utilized for the preparation of the foil. The amount was presented in taka and analyzed for the price of per kg of foil.

3.11 Sensory evaluation

To ascertain whether consumers would generally find the finished product acceptable, sensory evaluation was conducted. A panel of tasters assessed the produced product's crispiness and consumer acceptability. The panel test was conducted on the grounds of the laboratory where the panelists worked for AKCGD. Ten participants in the panel were given the product, which was packaged with various layers of flexible laminate. There were four laminate formulations that had samples A, B, C, and D encoded onto them. The panelists sampled the four samples without being told what the formulas were. The panelists were asked to give the products' sensory attributes—including their look, color, flavor, texture, crispiness, and general acceptability—the proper scores. Of course, this method does not reflect actual consumer perception, but it clearly suggests characteristics that a high-quality product should have. They scored after tasting four samples and expressing their opinions. Using nine point Hedonic measures, sensory evaluation of the four samples' qualitative qualities (taste, look, flavor, mouth feel, crispiness, and overall acceptability) was conducted (Larmond, 1977). The scales were set up so that:

Table 3.1: Rating Scale for sensory evaluation

Ranks	Scores
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slight	4
Dislike moderately	3
Dislike very much	2
Dislike Extremely	1

Chapter 4: Results

4.1 Water Vapor Transmission Rate (WVTR)

Sample: A

The results of Water Vapor Transmission Rate for “Sample A” are presented in the following table 4.1. The Water Vapor Concentration value were changed with time to time and finally stable at 0.4910 g/(m^2.24h)

Composition of Foil:

4 Layer : 12μ PET + 2μ Ink + 10 GSM Extrusion PE + 12μ MPET + 2μ Adhesive + 20μ PE = 58μ (±5μ)

Sealing Strength: 65.62 Newton Force .Bursting: 130 kpa

Table: 4.1(A) WVTR result for Sample Foil (A)

Materials : Chanachur 16 gm	Temperature: 38°C
Test Date: 2021-12-25	Humidity: 90%
Source: Finished Goods Pouch Form	Specificaition: 12μ PET + 2μ Ink + 10 GSM Extrusion PE + 12μ MPET + 2μ Adhesive + 20μ PE = 58μ (±5μ)
Test Result: 0.4910	

Time (Min)	WVT g/(m^2.24h)	Time (Min)	WVT g/(m^2.24h)	Time (Min)	WVT g/(m^2.24h)
2021-12-25 17:21	17.1198	2021-12-25 23:39	0.5376	2021-12-26 06:58	0.5329
2021-12-25 18:35	15.7448	2021-12-25 23:46	0.4781	2021-12-26 07:15	0.5064
2021-12-25 18:55	13.6862	2021-12-26 01:33	0.4660	2021-12-26 08:32	0.4817
2021-12-25 19:48	10.6381	2021-12-26 02:50	0.4696	2021-12-26 09:49	0.4919
2021-12-25 20:08	7.2514	2021-12-26 03:27	0.4818	2021-12-26 10:26	0.5147
2021-12-25 21:25	4.1206	2021-12-26 04:24	0.4980	2021-12-26 11:23	0.5038
2021-12-25 22:42	1.6988	2021-12-26 05:41	0.5131	2021-12-26 12:57	0.4910

Sample : B

The results of Water Vapor Transmission Rate for “Sample B” are presented in the following table 4.1(B). The Water Vapor Concentration value were changed with time to time and finally stable at 0.4138 g/(m^2.24h)

Composition of Foil:

4 Layer : 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 30µ PE = 68µ (±5µ)

Sealing Strength: 70.12 Newton Force

Bursting: 155 kpa

Table: 4.1(B) WVTR result for Sample Foil (B)

Materials : Chanachur 16 gm	Temperature: 38°C
Test Date: 2021-12-30	Humidity: 90%
Source: Finished Goods Pouch Form	Specificaition: 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 30µ PE = 68µ (±5µ)
Test Result: 0.4138	

Time (Min)	WVT g/(m^2.24h)	Time (Min)	WVT g/(m^2.24h)	Time (Min)	WVT g/(m^2.24h)
2021-12-30 14:42	9.2202	2021-12-30 20:38	0.5376	2021-12-31 05:52	0.7788
2021-12-30 15:48	7.9308	2021-12-30 21:40	0.4781	2021-12-31 06:15	0.7166
2021-12-30 16:37	5.8840	2021-12-31 00:02	0.4660	2021-12-31 07:36	0.6263
2021-12-30 17:40	4.1325	2021-12-31 01:24	0.4696	2021-12-31 08:58	0.5740
2021-12-30 18:12	3.2706	2021-12-31 02:46	0.4818	2021-12-31 09:20	0.5199
2021-12-30 19:34	1.8124	2021-12-31 03:08	0.4980	2021-12-31 10:42	0.4840
2021-12-30 19:56	1.2314	2021-12-31 04:30	0.5131	2021-12-31 11:58	0.4138

Sample : C

The results of Water Vapor Transmission Rate for “Sample C” are presented in the following table 4.1(C). The Water Vapor Concentration value were changed with time to time and finally stable at 0.3496 g/(m^2.24h)
Composition of Foil:

4 Layer : 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 35µ PE = 73µ (±5µ)

Sealing Strength: 80.10 Newton Force

Bursting: 165 kpa

Table: 4.1(C) WVTR result for Sample Foil (C)

Materials : Chanachur 16 gm	Temperature: 38°C
Test Date: 2022-01-03	Humidity: 90%
Source: Finished Goods Pouch Form	Specificaition: 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 35µ PE = 73µ (±5µ)
Test Result: 0.3496	

Time (Min)	WVT g/(m^2.24h)	Time (Min)	WVT g/(m^2.24h)	Time (Min)	WVT g/(m^2.24h)
2022-01-03 14:28	17.1198	2022-01-03 22:37	0.5376	2022-01-04 06:39	0.5329
2022-01-03 15:35	15.7448	2021-01-03 23:35	0.4781	2021-01-04 07:46	0.5064
2022-01-03 15:48	13.6862	2022-01-04 12:43	0.4660	2022-01-04 08:33	0.4817
2022-01-03 18:49	10.6381	2021-01-04 01:30	0.4696	2021-01-04 09:50	0.4019
2022-01-03 19:08	7.2514	2022-01-04 03:27	0.4818	2022-01-04 10:25	0.3847
2022-01-03 20:36	4.1206	2022-01-04 04:24	0.4980	2022-01-04 11:35	0.3659
2021-01-03 21:52	1.6988	2021-01-04 05:41	0.5131	2021-01-04 12:45	0.3496

Sample: D

The results of Water Vapor Transmission Rate for “Sample D” are presented in the following table 4.1(D). The Water Vapor Concentration value were changed with time to time and finally stable at 0.4949 g/(m^2.24h)

Composition of Foil:

3 Layer : 12µ PET + 2µ Ink + 12µ MPET + 2µ Adhesive + 43µ PE = 73µ (±5µ)

Sealing Strength: 90.35 Newton Force

Bursting: 175 kpa

Table: 4.1(D) WVTR result for Sample Foil (D)

Materials : Chanachur 16 gm	Temperature: 38°C
Test Date: 2022-01-06	Humidity: 90%
Source: Finished Goods Pouch Form	Specificaition: 12µ PET + 2µ Ink + 12µ MPET + 2µ Adhesive + 43µ PE = 73µ (±5µ)
Test Result: 0.4949	

Time (Min)	WVT g/(m^2.24h)	Time (Min)	WVT g/(m^2.24h)	Time (Min)	WVT g/(m^2.24h)
2022-01-06 13:21	14.2598	2022-01-06 20:21	0.5876	2022-01-06 03:21	0.5123
2022-01-06 14:35	12.4548	2022-01-06 21:35	0.5781	2022-01-06 04:35	0.5164
2022-01-06 15:55	11.3562	2022-01-06 22:55	0.4820	2022-01-06 05:55	0.5318
2022-01-06 16:48	8.8581	2022-01-06 23:48	0.4636	2022-01-06 06:48	0.5221
2022-01-06 17:08	6.2614	2022-01-06 12:08	0.4712	2022-01-06 07:08	0.5138
2022-01-06 18:25	3.2256	2022-01-06 01:25	0.4850	2022-01-06 08:25	0.5052
2022-01-06 19:42	1.3522	2022-01-06 02:42	0.5221	2022-01-06 09:42	0.4949

4.2 Moisture Content:

Table: 4.2 Moisture Content of Extruded Snacks (Chanachur)

Sample	Composition of Foil	Moisture Content % (Before Packing)	Moisture Content % (After Packing)				
			1st Month	2nd Month	3rd Month	4th Month	5th Month
Sample : A	12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 20µ PE = 58µ (±5µ)	1.33%	2.27 %	2.36 %	2.56%	2.56%	2.58%
Sample : B	12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 30µ PE = 68µ (±5µ)	1.33%	1.41%	1.48%	1.52%	1.53%	1.58%
Sample : C	12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 35µ PE = 73µ (±5µ)	1.33%	1.42%	1.46%	1.54%	1.55%	1.57%
Sample : D	12µ PET + 2µ Ink + 12µ MPET + 2µ Adhesive + 43µ PE = 73µ (±5µ)	1.33%	1.58%	1.66%	1.76%	1.89%	2.10%

From the figure 4.1, Moisture content in sample A was calculated in highest amount (2.58%) and lowest (1.57%) in sample C.

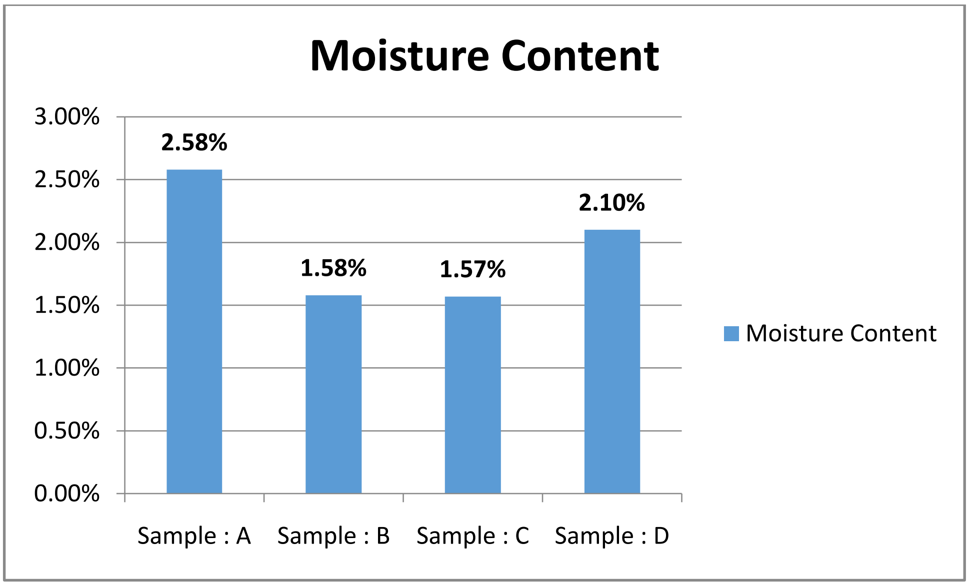

Figure 4.1: Comparison of moisture content among four composition of flexible plastic foil

4.3 Sensory evaluation

The sensory characteristics evaluated across the panel did not differ significantly (table 4.8). Sample C got the highest acceptance rate across all criteria. When compared to the other samples, sample A received the lowest acceptability rating.

Table 4.3: Hedonic rating test for sensory evaluation of Chanachur inside the different composition foil.

Formulation	Taste	Crispiness	Flavor	Appearance	Overall Acceptability
Sample A	7.07	8.07	7.87	7.60	7.73
Sample B	7.73	8.20	8.00	7.87	8.00
Sample C	7.80	8.60	8.20	8.47	8.60
Sample D	7.73	8.33	7.93	8.27	7.93

Chapter 5: Discussions

5.1 Moisture Barrier properties of flexible plastic Materials:

On most data sheets, moisture is represented as WVTR (water vapor transmission rate), which is the steady-state rate at which water vapor permeates through a film under specific circumstances. The WVTR of most plastic films is low. The pertinent measurements are typically given in grams per square meter per day (gm/m^2/24 hours) under conditions of 37.8°C and 90% relative humidity. WVTR increases as temperature or pressure increases together with humidity.

The circumstances of the measurement have a significant impact on the outcome. The sample should be the same thickness, and both the temperature and humidity gradients across it need to be measured, controlled, and documented with the results. Without mentioning these circumstances, an MVTR result is almost irrelevant.

The WVTR is an important factor for flexible packaging materials. Moisture absorption of extruded snacks (Chanachur) is also prevented by low WVTR of foil. In this study Sample C were found lower WVTR value 0.3496; while Sample A had the highest value 0.4949.

All the results fall within the range between 0.3496 to 0.4949. Different thickness of foil provided different WVTR value, may be the main cause behind the significant change of WVTR value.

To add another layer to the polyester film roll material already on hand, extrusion coating uses a blown or cast film method. The qualities of paper can be enhanced with this procedure by coating it with polyethylene to increase its water resistance. Additionally, two additional materials can be joined together by using the extruded layer as an adhesive.

Using a layer of molten resin extruded through computer-controlled extruder dies with sophisticated gauge controls, extrusion lamination unites two sheets (nuclear gauge monitoring and automatic profile control). Combined with the molten resin, the two layers create a multilayered flexible packaging lamination.

Extrusion lamination can be paired with adhesive lamination to make the final flexible packaging lamination, or it can be repeated until the flexible packaging structure is completed.

The results showed that the WVTR value had a significant change among the samples that contain extrusion PE ranged between 0.3496 to 0.4138.

5.2 Moisture Absorption Rate:

Low-density polyethylene is recognized for its flexibility, resistance to moisture, durability, toughness, chemical resistance, light weight, sealing qualities, and affordability. Due to its weak gas resistance, inability to hold ink, and high inclination to produce a static charge that may collect dust, which can be ugly on a retail shelf, it cannot be used alone. Polyethylene films (with a thickness range of 58 to 73µ) are taken into consideration for receiving some prediction rules in order to evaluate the impact of film thickness on the gas movement. According obtained data it was estimated that films based on met-allized PET have good mechanical and barrier proper- ties and can be used for specific applications. The results for the moisture absorption are summarized in the Fig-4.1. The barrier to moisture absorption remarkably increased after coating. The results showed lower moisture content value that contains extrusion PE ranged between 1.57% to 1.58%. All samples can be seen to have good barrier qualities that adhere to the requirements for food packing.

5.6 Sensory Evaluation:

To determine which sample had the highest proportion of organoleptically acceptable components, sensory analysis of Chanachur (extruded snacks) was conducted. Sensory analysis data from Table 4.2 shows that Chanachur packed with foil of 73 µ containing extrusion PE (sample C) scored highest in overall acceptability of 8.60. It may be due to taste, Crispiness and appearance. Whereas Chanachur packed with foil of 58 µ without extrusion PE (Sample A) scored lowest in all parameters. The overall acceptability level of sample B was nearest with the value of sample C. The crispiness score was affected by the composition of foil. Highest mean score of acceptability 8.60 in sample C in hedonic rating scale denoted “Like Very Much”. From present investigation, it was concluded that Chanachur packed with foil of 73 µ containing extrusion PE was found to be better organoleptically than other compositions.

Chapter 6: Conclusion

Because it is a delicious & tempting snack, extruded snacks (Chanachur) are a well-liked food item in ready-to-eat foods. According to the needed shelf-life and wrapping machine performance, new trends in the snack food and ready-to-eat food market industry have opened up several opportunities for the development of creative packaging materials. The most widely used alternative to traditional waxed paper and aluminum foil as a packaging medium is plastic films and laminates. For a variety of snack food packaging, flexible plastics, composite containers, and tinplate containers are frequently employed. In the last few years, the snack food business has experienced tremendous expansion. Innovative plastic packaging has been made possible by multinational corporations and sizable domestic firms entering both domestic and foreign markets. It was determined that films based on Extrusion-coated metalized PET provides great barrier qualities and can be used to cover snack foods. All considered multi-layer high-barrier foils with minimal permeability of CO_2, O_2 and N_2 molecules (produced under estimated optimal technology parameters) were convenient for the preservation of snack products. Benefits of extrusion lamination can includes increasing moisture barrier properties and greater puncture resistance. This study points out a prosperous probability of using different composition of foil for the advantage of manufacturers, processors and the consumers in Bangladesh. Further study is important for research with other necessary composition for trial with different types of laminated foil used in snacks packaging.

Chapter 7: Recommendations and Future Perspectives

It is not surprising that people are eating more snacks. Snacks are a convenient way for consumers to get nutrition on the go, and they look for packaging that fits their busy lives. Extruded snacks (Chanachur) could be a good source of the nutrients and energy as these are available in rural areas of Bangladesh. We have reached a successful conclusion about the development of materials for snack food (Chanachur) packaging. Modern food industries can use this packaging materials for large scale of snacks production. The following recommendations and study opportunities are offered based on the current investigation.

a) The current research could be improved upon to verify the experimental results.

b) The composition may be modified further and may try for making different types of laminated foil with various thicknesses.

c) Such types of research should be done for other food products like Biscuits, Chips, Crackers etc. available in markets.

d) Modern packaging and storage condition would be developed for the betterment of Snacks products.

e) The discovery that flexible packaging preserves and indicates the freshness for the products it covers will be useful. Flexible packaging really increases the shelf life of a variety of goods, particularly food, and has a favorable sustainability profile.

f) Assist in making packaging light and portable so that it is simple to store at home.

References

Abbas, M., Buntinx, M., Deferme, W. and Peeters, R. (2019) (bio)polymer/zno nanocomposites for packaging applications: A review of gas barrier and mechanical properties. Nanomaterials 9: 10, 1494

Biji, K. B., Ravishankar, C. N., Mohan, C. O. and Srinivasa Gopal, T. K. (2015) Smart packaging systems for food applications: A review. Journal of Food Science and Technology 52: 10, 6125

Bastos-Cardoso, I., Zazueta-Morales, J. de J., Martínez- Bustos, F., Kil-Chang, Y. (2007): Development and characterization of extruded pellets of whole potato (Solanum tuberosum L.) flour expanded by microwave heating. Cereal Chem. 84(2), 137–144.

Bahramparvar, M., Moghaddam, T. M., Razavi, S. M. A. (2012): Effect of deep-fat frying on sensory and textural attributes of pellet snacks. J. Food Sci. Technol. 51(12), 3758–3766

Balaban-Đurđev P. (2006). Influence of flexo printing process on characteristics of polymer packaging foils. Masters Thesis, Faculty of Technical Sciences, University of Novi Sad, Serbia.

Choi, I.-D., Phillips, R. D., Resurreccion, A. V. A. (2007): Consumer-Based Optimization of a Third-Generation Product Made from Peanut and Rice Flour. J. Food Sci. 72(7), 443–449.

Chauhan G.S., Bains G.S. 1990. Equilibrium moisture content, BET monolayer moisture and crispness of extruded rice-legume snacks. International Journal of Food Science & Technology 25: 360-363.

Camacho-Hernandez, I. L., Zazueta-Morales, J. J., Gallegos- Infante, J. A., Aguilar-Palazuelos, E., Rocha-Guzman, N. E., Navarro-Cortez, R. O., Jacobo-Valenzuela, N., Gomez-Aldapa, C. A. (2014): Effect of extrusion conditions on physicochemical characteristics and anthocyanin content of blue corn third-generation snacks. Cyta-J. Food. 12(4), 320–330

Çakıcı, L. (1973). Developments in Packaging and Packaging Field Problems in Business
Administration, AÜ Faculty of Political Sciences Publication: 356, Ankara

C.M.D. Man , Modern Food Packaging, Packaging of Snack Foods

Dana, D., Sam Saguy, I. (2006): Review : Mechanism of oil uptake during deep- fat frying and the surfactant effect- theory and myth. Adv. Colloid Interfac. 128–130, 267– 272

Dobrucka, R. C. (2015). Intelligent Food Packaging- Research And Development. Scientific Journal of Logistics, LogForum 11 (1), 7-14.

Dilber, F., Dilber, A., & Karakaya, M. (2012). Importance of Packaging in Food and Its Impact on Consumer Buying Behavior (Karaman city example). Gumushane University Communication Faculty Electronics Magazine. March 2012.

Desnica E., Ašonja A., Mikić D. & Stojanović B. (2015). Reliability of model of bearing assembly on an agricultural of Cardan shaft. Journal of the Balkan Tribological Association 21(1): 38–48.

E. E. Katz and T. P. Labuza, (1981) "Effect of Water Activity on the Sensory Crispness and Mechanical Deformation of Snack Food Products," Journal of Food Science, Vol. 46, No. 2, pp. 403-409.

Ebnesajjad S. (2013). Plastic Films in Food Packaging, pp. 53. Elsevier, Netherlands

Fotie G., Rampazzo R., Ortenzi M.A., Checchia S., Fessas D. & Piergiovanni L. (2017). The effect of moisture on cellulose nanocrystals intended as a high gas barrier coating on flexible packaging materials. Polymers 9: 415

Huber, G. (2001): Snack foods from cooking extruders. In: Snack Foods Processing, Lusas, E. W., Rooney, L. W. (eds.), Boca Raton, USA: CRC Press, pp. 356–359.

Huber, G. R., Rokey, G. J. (1990): Extruded Snacks. In: Snack Food, Huber, G. R. (ed.), New York, USA: Van Nostrand Reinhold, pp. 123–129.

Hsieh, F., Hu, L., Huff, H.E., and Peng, I.C. (1990), Effects of water activity on textural characteristics of puffed rice cake, Lebensmittel Wissenschaft und Technologie, Vol. 23, #6, pp. 471-473

Hertlein J. (1997). Untersuchung über Veränderung der Barriereeigenschaften metallisierter Kunststofffolien beim maschinellen Verarbeiten. Dissertation. Technical University of Munich, Germany. (In German)

Joseph F. Hanlon, Robert J. Kelsey, Halley F. Forcinio; (1998): Handbook of Package Engineering, Third Edition

Izdebska J. & Thomas S. (2015). Printing on Polymers, Fundamentals and Applications. Elsevier, Netherlands

Katz, E.E. , Labuza, T.P.(1981), The effect of water activity on the sensory crispness and mechanical deformation of snack food products, J. Food Sci. , Vol. 46, pp.403-409

Kim, D. and Seo, J. (2018) A review: Breathable films for packaging applications. Trends in Food Science & Technology

Lee D.S., Yam K.L., Piergiovanni L. 2008. Food Packaging Science and Technology. Boca Raton, Florida: CRC Press.

Larmond E. 1977. Laboratory methods for sensory evaluation of food. Research Branch, Canada Dept. of Agriculture.

Majid, I., Ahmad Nayik, G., Mohammad Dar, S. and Nanda, V. (2018) Novel food packaging technologies: Innovations and future prospective. Journal of the Saudi Society of Agricultural Sciences 17: 4, 454

Matz, S. A. (1993) Puffed snacks. In: Snack Food Technology, pp. 159–172.

Meritaine da, R., de Souza, M. M. and Prentice, C. (2018) Biodegradable films: An alternative food packaging vol, edn. Elsevier.

Moscicki, L. (2011): Snack Pellets. In: Extrusion-Cooking Techniques, Applications, Theory and Sustainability, Moscicki, L. (ed.), Weinheim, Germany: WILEY-VCH Verlag & Co. KGaA, pp. 81-89.

Mo, C., Yuan, W., Lei, W. and Shijiu, Y. (2014) Effects of temperature and humidity on the barrier properties of biaxially-oriented polypropylene and polyvinyl alcohol films. Journal of Applied Packaging Research 6: 1, 40

Market Publishers Report Database (2012). Food and Beverage Packaging Trends in the U.S.: Consumer Viewpoints and Marketer Opportunities, June, 1, 2012

Marangoni Junior L., De Oliveira L.M., Balardin H.D.F., Cristianini M., Padula M. & Anjos C.A.R. (2020). Influence of high-pressure processing on morphological, thermal and mechanical properties of retort and metallized flexible packaging. Journal of Food Engineering 273: 109812

Mrkić S., Galić K. & Ivanković M. (2007). Effect of temperature and mechanical stress on barrier properties of polymeric films used for food packaging. Journal of Plastic Film and Sheeting 23(3): 239–256.

Navarro-Cortez, R. O., Aguilar-Palazuelos, E., Zazueta- Morales, J. J., Castro-Rosas, J., Hernández-Ávila, J., Gómez-Aldapa, C. A, Aguirre-Tostado, F. S. (2014): Microstructure of an Extruded Third-Generation Snack Made from a Whole Blue Corn and Corn Starch Mixture. Int. J. Food Process. Technol. 1, 10–17.

Odabaşı, Y., & Oyman, M. (2005). Marketing Communications Management, Mediacat Press, Fifth Edition, İstanbul

Piringer O.-G., Baner A.L. (Eds). 2008. Plastic Packaging Interactions with Food and Pharmaceuticals, 2nd edn. Weinheim, Germany: Wiley-VCH.

Peng, X., Song, J., Nesbitt, A., Day, R. (2013): Microwave foaming of starch-based materials (I) thermo- mechanical performance. J. Cell. Plast. 49(3), 245-258.

Palić N., Slavković V., Jovanović Ž., Živić F. & Grujović N. (2019). Mechanical behaviour of small load bearing structures fabricated by 3D printing. Applied Engineering Letters 4(3): 88–92.

Perić-Maretić K., Bates I. & Modrić D. (2014). Comparison of colorimetric values of prints made with cyan ink on different polymer materials. Proceedia Engineering 69: 1556–1561.

Riaz, M. N. (2006): Extruded Snacks. In: Handbook of Food Science Technology, and Engineering, Volume 4, Hui, Y. H. (ed.), Boca Raton, USA: CRC Press, pp. 168/6-168/7.

Robertson, G. L. (1993): Food Packaging- Principles and Practice. New York, USA: Marcel Dekker, pp. 383-391.

Robertson G.L. 2006. Food Packaging Principles and Practice, 2nd edn. Boca Raton, Florida: CRC Press

Rubino M., Tung A.M., Yada S. & Britt I.J. (2001). Permeation of oxygen, water vapor, and limonene through printed and unprinted biaxially oriented polypropylene films. Journal of Agricultural and Food Chemistry 49(6): 3041–3045

Sevatson, E., & Huber, G. R. (2000): Extruders in Food Industry. In: Extruders in Food Applications, Riaz, M. N. (ed.), Boca Raton, USA: CRC Press, pp. 193–204

Sjoqvist, M., Gatenholm, P. (2007): Effect of Water Content in Potato Amylopectin Starch on Microwave Foaming Process. J. Polym. Environ. 15, 43–50.

Shieh, C. J., Chang, C.-Y., Chen, C.-S. (2004): Improving the texture of fried food. In: Texture in food, Kilcast, D.(ed.), New York, USA: CRC Press. Pp. 501-523.

Selke E.M.S. & Culter J. (2016). Plastics Packaging, 3 rd edition, Hanser Publishers, Munich, Germany

Smithers (2021). Flexible packaging market to grow at 3.4% across 2021–2026.

ShaguftaIshteyaq A., Asianeelam, Omm-e-hany & Syed J.M.(2019). Physical properties and biodegradable study of metallized and non-metalized polypropylene (pp) films: a comparative research. Advances in Biotechnology & Microbiology 12(3): 555838

Siracusa V. (2012). Food packaging permeability behaviour: a report. International Journal of Polymer Science 2012: 30202

Sangroniz A., Zhu J., Tang X., Etxeberria A., Chen E.Y.X. & Sardon H. (2019). Packaging materials with desired mechanical and barrier properties and full chemical recyclability. Nature Communications 10: 3559

Susan E. M. Selke, John D. Culter, Ruben J. Hernandez; Hanser (2004): Plastics Packaging- Properties, Processing, Applications and Regulations 2nd Edition

Standard Test Methods for Water Vapor Transmission of Materials ASTM International

Tovar-Jiménez, X., Caro-Corrales, J., Gómez-Aldapa, C. A., Zazueta-Morales, J., Limón-Valenzuela, V., Castro- Rosas, J., Hernández-Ávila, J., Aguilar-Palazuelos, E. (2015): Third generation snacks manufactured from orange by-products: physicochemical and nutritional characterization. J. Food Sci. Technol. 52(10), 6607– 6614

Underwood, R. (2003). The communicative power of product packaging: Creating brand identity via lived and mediated Experience. Journal of Marketing, 11(1)

Van der Sman, R. G. M., Broeze, J. (2014a): Multiscale analysis of structure development in expanded starch snacks. J. Phys. Condens. Matter 26, 1–11.

Van der Sman, R. G. M., Broeze, J. (2014b): Function Effects of salt on the expansion of starchy snacks : a multiscale analysis Multiscale model. Food Funct. 5, 3076–3082

Van Laarhoven, G. J. M., Staal, G. (1991): Rheology of the Paste from Gelatinization by Extrusion During the Production of Third-Generation Snacks. J. Food Eng. 14, 53–70.

Wikström, F., Williams, H., Verghese, K. and Clune, S. (2014) The influence of packaging attributes on consumer behaviour in food-packaging life cycle assessment studies-a neglected topic. Journal of Cleaner Production 73, 100

William E. Brown; Marcel Dekker Inc. (1992): Plastics in Food Packaging-Properties, Design and Fabrication.

Walter Soroka. (1999) Institute of Packaging Professionals, Fundamentals of Packaging Technology, Second Edition.

Yam K.L. (Ed). 2009. The Wiley Encyclopedia of Packaging Technology, 3rd edn. New York: John Wiley & Sons Inc.

Żołek-Tryznowska Z., Rombel M., Petriaszwili G., Dedijer S. & Kašiković N. (2020). Influence of Some Flexographic Printing Process Conditions on the Optical Density and Tonal Value Increase of Overprinted Plastic Films. Coatings 10: 816

Appendices

Appendix A: Questionnaire for Hedonic test of Chanachur (Extruded Snacks)

Name of the Taster: ………………   Date: ……….

Please taste these samples and rate each one on four sensory criteria—color, flavor, texture, and overall acceptability—to determine how much you like or dislike it. By selecting the option that best expresses how you feel about the sample, please provide a justification. Use the appropriate scale to demonstrate your perspective. Keep in mind that nobody else can tell what you like. We will benefit from hearing how you truly feel. Regarding taste, crispiness, flavor, appearance, and overall acceptability

The scale is arranged such that; Like extremely =9, Like very much =8, Like moderately =7, Like slightly=6, Neither like nor dislike =5, Dislike slightly =4, Dislike moderately =3, Dislike very much =2, and Dislike extremely =1.

Here,

A- Chanachur Packed with foil compostion of 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 20µ PE = 58µ (±5µ).
B- Chanachur Packed with foil compostion of 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 30µ PE = 68µ (±5µ).
C- Chanachur Packed with foil compostion of 12µ PET + 2µ Ink + 10 GSM Extrusion PE + 12µ MPET + 2µ Adhesive + 35µ PE = 73µ (±5µ).
D- Chanachur Packed with foil compostion of 12µ PET + 2µ Ink + 12µ MPET + 2µ Adhesive + 43µ PE = 73µ (±5µ).

Hedonic	Taste				Crispiness				Flavor				Appearance				Overall Acceptability			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Like Extremely																				
Like very much																				
Like moderately																				
Like slightly																				
Neither like or dislike																				
Dislike slightly																				
Dislike moderately																				
Dislike very much																				
Comments																				

Appendix B : Photo Gallery

Brief Biography

Faridul Wahid passed the Secondary School Certificate Examination in 2001 from Palishara High School, Hajigonj, Chandpur, and then Higher Secondary Certificate Examination in 2003 from Kabi Nazrul Government College, Dhaka. He obtained his B.Sc. (Engineering) in Food Engineering and Tea Technology from the Faculty of Applied Science and Technology at Shahjalal University of Science Technology, Sylhet, Bangladesh. Now, he is a candidate for the degree of Master of Science in Food Chemistry and Quality Assurance under the Department of Applied Chemistry and Chemical Technology, Chattogram Veterinary and Animal Sciences University (CVASU). He has an immense interest to work in improving the quality of food products through proper guidance and suggestions and to create awareness among people about food safety and quality.