# ELIMINATION OF PACKAGE BURSTING OF SNACK PRODUCTS IN CERTAIN ENVIRONMENTAL CONDITIONS

BY

A.M.D. DILINI NIROSHA

99/A/AS/034

Thesis submitted in partial fulfillment of the requirement for the Degree of

Bachelor of Science

in

Food Science and Technology

Faculty of Applied Sciences

Sabaragamuwa University of Sri Lanka.

Buttala

2003

## DECLARAION

The work described in this thesis was carried out by me at the Uswatte golden Chips (pvt) Ltd and Faculty of Applied Science under the supervision of Mr. Indika Perera and Mr. Jagath Wansapala a report on this has not been submitted to any other university for another degree.

A.M.D. Dilini Nirosha
99/A/AS/034

..............................................
(Signature of the student)

23 /04 /2003
(Date)

**Certified by,**

**External Supervisor**
Mr.Indika Perera
Factory Manager
Uswatte Golden Chips (Pvt) Ltd.,
Borupona,
Ratmalana.

..............................................
(Signature/ External Supervisor)

23 /04 /2003
( Date)

**Internal Supervisor**
Mr.Jagath Wansapala
Co-ordinator Food Science & Technology
Department of Natural Resources,
Faculty of Applied Science,
Sabaragamuwa University of Sri Lanka
Buttala.

..............................................
(Signature/ Internal Supervisor)

28/04/2003
(Date)

**Head of the Department**
Prof. Mahinda Rupasinghe,
Head/ Department of Natural Resources
Faculty of Applied Science,
Sabaragamuwa University of Sri Lanka
Buttala.

..............................................
(Signature/ Head of the department)

28/4/2003
(Date)

*AFFECTIONATELY DEDICATED TO*

*MY EVER LOVING PARENTS*

*&*

*TEACHERS*

## ACKNOWLEDGEMENT

First and foremost I wish to express my deepest gratitude to my internal supervisor Mr.Jagath Wansapala, Co- ordinator, Food Science and Technology, Department of Natural Resources, Faculty of Applied Science, Sabaragamuwa University of Sri Lanka for his assistance, encouragement, guidance and his valuable time to make this study a success.

I express my sincere gratitude to Mr.Nihal Perera, Chairman, Uswatte Confectionery Works (Pvt) Ltd., Mr.Neville Perera, Director, Uswatte Confectionery Works (Pvt) Ltd., and Mr.C. Fernando, Production Manager, Uswatte Confectionery Works (Pvt) Ltd for providing the opportunity to carryout this study at Uswatte Golden Chips (Pvt) Ltd.

I express my sincere gratitude to Dr.Wicramarathne, the Dean, Faculty of Applied Science, Sabaragamuwa University of Sri Lanka and Prof. Rupasinghe, Head, Department of Natural Resources, Faculty of Applied Science, Sabaragamuwa University of Sri Lanka for guiding me towards a successful completion.

My deepest gratitude is express to Mr.Indika Perera, Factory Manager, Uswatte Golden Chips (Pvt) Ltd who gave me individual support throughout my project. I would also like to extend my thanks to all the staff members including Jagath, Marie and Shalika who were always willing to give their support and assistance to me throughout the project.

I wish to express my gratitude to Mr.Niranjan, Area Manager, Uswatte Confectionery Works (Pvt) Ltd who was always willing to give his support to my field works.

Finally, I express my heart-felt gratitude towards the lectures especially Ms.C.H.Rathnaweera for their co-operation throughout my study and my colleagues for their individual help and guidance to me at all times.

# ABSTRACT

Extruded snacks like Tipi Tip are marketed in packs that are formed from triple laminated aluminum foil. It is a multilayer packaging material and formed from thermal lamination process. To having a better quality product and longer shelf life with visibility, before sealing certain amounts of $N_2$ gas is flushed into the pack.

These packs are distributed to the up country also. With respect to the altitude there is a low environmental condition in the up country. As a result packs are inflated while reaching to the up country. From them some of packs burst out the gas. To eliminate this it is necessary to find the packaging material characteristics change with the environmental conditions and suitable parameters to eliminate this packing problem or find the best packaging material by changing the thickness and packing films of the triple laminated aluminum foil.

Effects of environmental temperature, vertical sealing temperatures on vertical seal and anti-wrinkling and anti blocking powder application of the film on package bursting were tested. These variables were rejected at 5% significant difference level. These variables do not affect on package bursting. Environmental pressure gradient was tested and it affects on package bursting. It is accepted at 5% significant difference level. From existing packing materials in the institute (PET / PE / CO+POLYMER / ALU / PE – Strong Pack (SP), PET / INK / PE / ALU / EAA – Flexi Pack (FP), PET / EXTN POLY / AL FOIL / EXTN POLY – N – Flex Industries Pack (IP)) SP was rejected at 5% significant difference level with flushing $N_2$.

Effects of different gas compositions inside the packs on package bursting were tested. Nitrogen gas was rejected at 5% significant difference level and better to use Carbon dioxide mixture of Carbon dioxide and Nitrogen.

And it was improved with gas absorbent ($CaCl_2$). It was accepted at 5% significant difference level. Depending on the result packs were produced with Carbon dioxide and its absorbent, there was no package bursting in upcountry. It was accepted at 5% significant difference level. Carbon dioxide does not affect on colour and taste of the product. SP was better with flushing Carbon dioxide with $CaCl_2$ too.

Most of the packs burst out the gas from vertical seal. They are burst along the folding line of vertical seal from under side was found. When bursting upper layer is delaminated and inside three layers are torn along the folding line. So increase the strength of the packs' body is needed. Developing the triple laminated aluminum foil using highly strength inner layer such as LLDPE or Metallacen was recommended.

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# CHAPTER 1
# Introduction

## 1.1 Introduction

Tipi tip is an extruded snack. It has porous structure and highly hydrophilic product. Extruded snacks are mixed with oily flavour. If moisture is available, product absorbs and causes to reduce crispness. So if moisture and oxygen are available product is caused to rancidity because of oily flavour. Because of the physical damages product is crushed. Also microorganisms (especially fungi) affect on the product, if the favourable conditions are available. To have a better quality product and longer shelf life with visibility, it is packed in a triple laminated aluminium foil (Flexible packaging film). Before sealing certain amount of $N_2$ gas is flushed into the pack.

Triple laminated aluminium foil is made by 3 type of flexible packaging films laminated with aluminium foil by thermal lamination process.

e.g. PET/INK/PE/ALU/PE

PET- Polyester film

PE- Polyethylene film

ALU- Aluminium foil

Triple laminated aluminium foil is used because of it has excellent barrier properties.

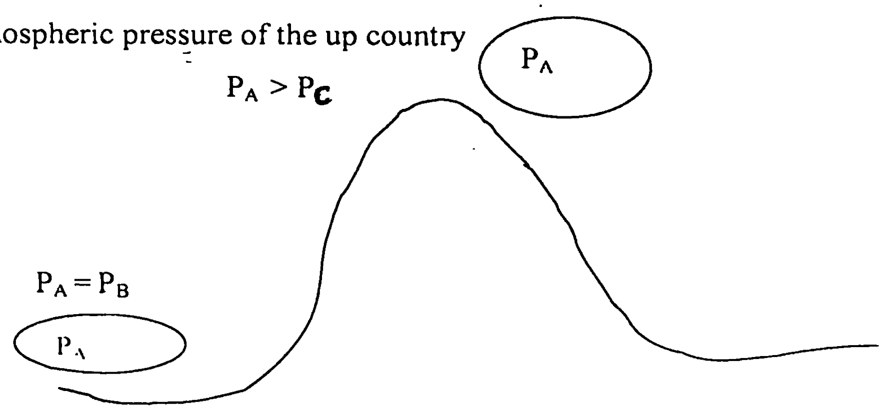
**How does the environmental aspects affect on packages.**

Normally atmospheric pressure and temperature reduce with respect to the height from sea level (altitude). Tipi tip is produced under the climatic conditions of low country. So inside gas pressure is similar to the atmospheric gas pressure of low country. Atmospheric pressure and temperature of up country is less than the low country. After distributing to the up country inside gas pressure of the pack is high. So the pressure of the inside the pack tries to keep pressure that similar to atmospheric pressure of up country.

$P_A$- Inside pressure of the pack

$P_B$- Atmospheric pressure of the low country

$P_C$- Atmospheric pressure of the up country



Then it is needed more volume to reduce the inside pressure. So inside gas seeks more volume. As a result pack is inflated.(Figure 1.1)

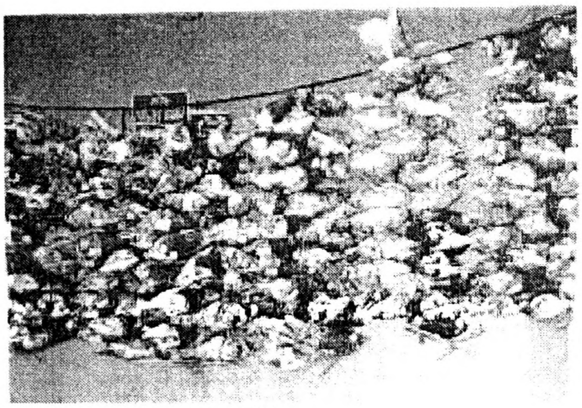


Figure 1.1 Inflated packs at Nuwara Eliya

Some packs burst out the inside gas from the place that easy to burst. Most of the packs will get burst from the place (line) that nearest to the vertical sealing. When bursting upper layer is delaminated and inside three layers are torn.

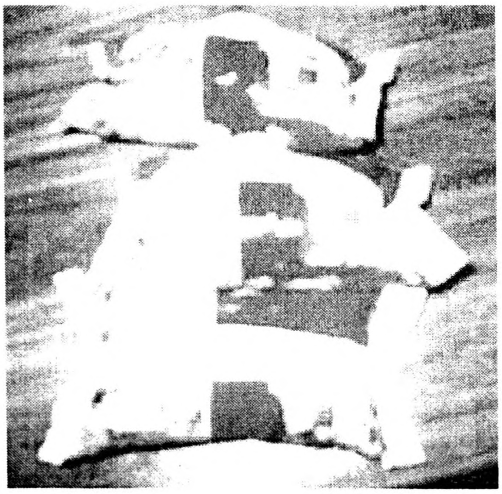


Figure 1.2 Burst packs

**1.2 Objectives**

- Find the packaging material conditions/ characters change with the environment conditions.
- Find the suitable parameters to eliminate this packing problem.
- Find the best packaging material by changing the thickness and packing films of the triple laminated aluminium foil.

# CHAPTER 2

## Review of Literature

### 2.1 History

Man has many competitors for him food he produces. Animals, particularly rodents, insects and micro organisms (moulds, yeast and bacteria), all cause wastage at various stages in the growth, harvesting, processing; storage, transport and sale of food. If micro organisms are permitted to flourish in food, they will make it unattractive, and it will waste by particularly bacteria, can affect food and render it poisonous to man, thereby causing sickness and even death. The provision of food, which is good and safe to eat, is therefore a duty of the food industry: the prevention of waste is essential to that industry and to a nation's economic well-being. Packing plays a decisive role in achieving the objectives of safety and waste prevention.

The earliest packaging materials were probably leaves from larger plants, which were used by early man to wrap meat from a kill. In early days when men lived by hunting and gathering, their nomadic existence necessitated some means of keeping food 'fresh' while they travelled. Animal skins were used for water and woven baskets were also employed.

It is perhaps inevitable that some of the landmarks in the fight to preserve food should concern the provisioning of armies. At the beginning of the nineteenth century Napoleon was finding it increasingly difficult to do this. The 'scorched earth' policy of his adversaries meant that it was not possible to live off the conquered territories, and the blockade by the British fleet deprived France of the sugar needed to preserve as fruit. He needed packaged foods that could be taken along with these armies, and he offered a prize of 2000 francs for suitable method of preservation: this was won in 1810 by a Frenchman, Nicolas Appert, for the development of the 'canning' process, although he, at that time, used glass jars.

Later in the nineteenth century, the Great Trek took place in America as the pioneers in their covered wagons spread out across the continent to establish their homesteads and plant their crops. Their survival until the first harvest was made easier by the dried and canned foods, which they took with them. The American canning industry grew quickly to meet these demands and then to provision the rival force in the American Civil war.

These Examples of the early use of packaged foods were concerned with survival, but they illustrate basic principles. Food must be available whenever there era people, and with modern population patterns this is seldom where it is grown. Food, in interesting variety, must be available all the year round, irrespective of the growing season. It must be presented in a way that is convenient to purchase and use, and in most instances this means that it must be packaged. (Paine F.A. & Paine H.Y. ,1992)

## 2.2 What is a packaging?

To appreciate the place of packaging in the world economy, we must know what it is and how it functions. Packaging has been defined in several ways. Table 2.1 lists three of the more fundamentals; (1) and (2) indicate that packaging contains and protects during transport and has a economic aspect. To ensure delivery; the package must at least provide information as to the address of the recipient, describe the product and perhaps explain how to handle the package and use the product. A little more through hand we recognize that packaging is part of the marketing process. (Figure 2.2)

Marketing may be defined as the identification, anticipation and satisfaction of customer need profitably. Packaging has also been described as a 'complex, dynamic, scientific and controversial segment of business. Packaging is certainly dynamic and is constantly changing. New materials need new methods, new methods demand new machinery, and new machinery results in better quality opens up new markets which require changes in packaging. The cycle then starts again.

Thus, at its most fundamental, packaging contains protects and preserves, and informs. At its most sophisticated, it provides two more functions. Those of selling and convenience, In a world where the quality of products is high, in many instances almost the only difference between competitive brands lies in the packaging, and only packaging influences the selling operations. We recall the last definition in table 1.1 packaging is a techno economic function aimed at minimizing costs of delivery while maximizing sales. (And hence profits) At this level, the value of –or even the need for the added functions is controversial, and as a result opinions vary as to whether packaging is a waste of material and energy, or is properly utilized for the conservation of goods and reduction of labour. There is no doubt, however, that in the post-fuel crisis world in which we now live, where materials are more expensive principally because of the extra cost of energy, we may well need to change our criteria of judgement. Containment, protection and information will always be essential in any packaging and these functions are basically conservation. How much we should spend on the 'selling' and 'convenience' functions and how far they are regarded as necessary; is a matter of discussion.

Table 2.1 Definitions of packaging.

| |
|---|
| (1) A coordinated system of preparing goods for transport distribution, storage, retailing and end-use. |
| (2) A means of ensuring safe delivery to the ultimate consumer in sound condition at minimum overall cost. |
| (3) A techno-economic function aimed at minimizing cost of delivery while maximizing sales (and hence profit). |

Source - Paine F.A. & Paine H.Y.,1992

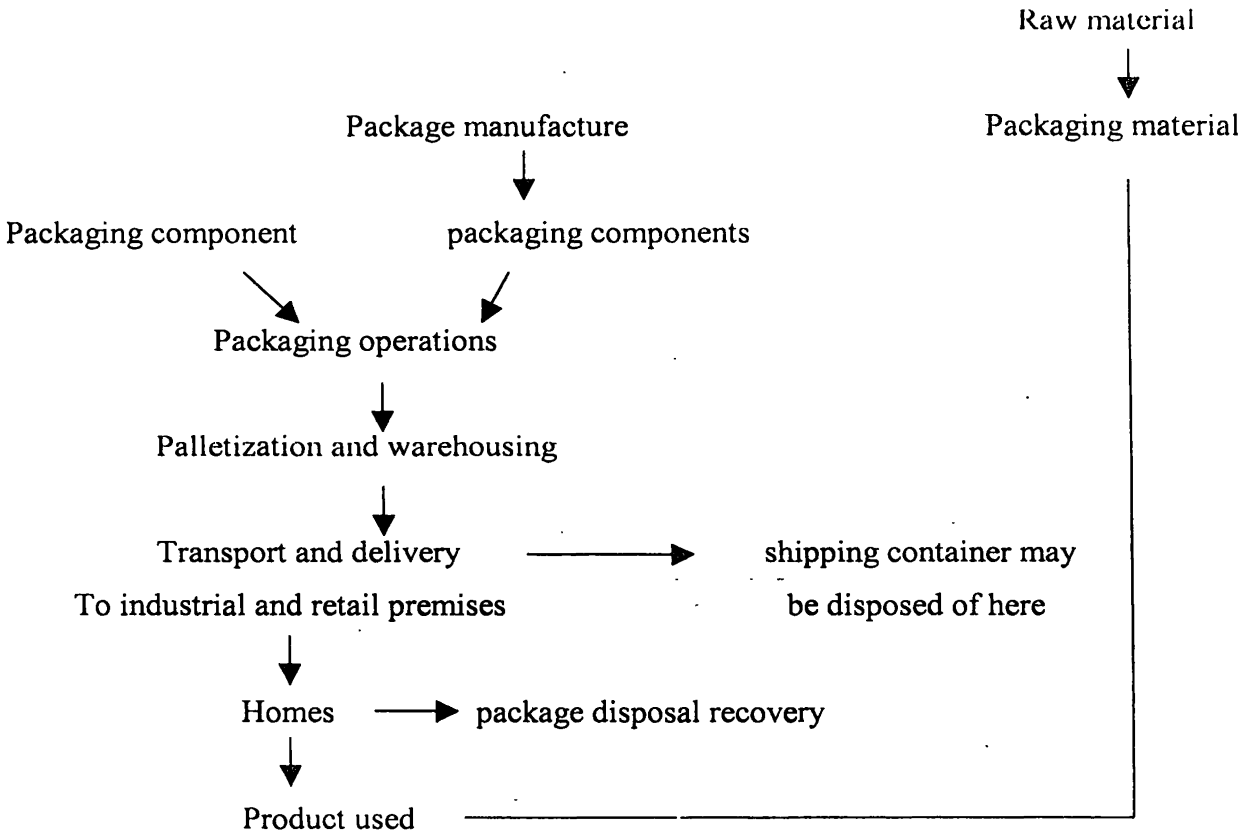



Figure 2.1 The marketing process and the packaging.
(Paine F.A. & Paine H.Y.,1992)

**2.3 Functions of packaging**

If the product is to reach the consumer in a sound condition, the packaging material will play an important role, and the retail package should be designed to meet the requirements, to provide protection, to be easy to handle, to provide a vehicle for a message and so on.

**Protection**

Extruded snacks are highly hydrophilic product and the purpose of the package is to protect it from the environment. That is dirt or other foreign bodies, micro organisms which can affect the keeping quality of snacks, gas barrier property, moisture barrier property, light which may cause discolouration or possibly oxidation of the fat. In addition the package must prevent loss of flavour volatile or the absorption of undesirable odours. Before sealing the gas is flushed into the package is essential to prevent the product from physical damages.

**Ease of handling**

Snack products usually exist in the form of fragile or crush. The retail package must provide a convenient means of handling the product in the factory, during storage and transport, and throughout the sale period in supermarkets and shops.

**Provide a message**

The printing and other graphic work on the exterior of the package will serve to provide the product with a "brand image" and/or display a message to persuade a potential buyer to purchase, and will contain the information proposed in the guidelines for food labelling such as:

- Identity of the product
- Name and address of the manufacturer
- Approximate chemical composition or nutritional data of the product, or the ingredients listed in descending order by weight
- Best before date
- Possible suggestions of recipes or the instructions for use

**Miscellaneous functions**

In general packaging materials, which is in direct contact with a foodstuff must be non toxic and no chemical reactions should take place between the material and the food product. It is against this general background that the following approaches to marketing snacks have evolved. Most important general requirement of food packages for the following:

- Non-toxic
- Product against contamination from micro organisms
- Act as a barrier to moisture loss or gain and $O_2$ ingress
- Product against ingress of odours or environmental toxicant
- filter out harmful UV light
- provide resistance to physical damages
- be transport
- be temper (change resistance)
- Easy to open
- have dispending (take out)
- be disposed off easily
- Meet size, shape and weight requirements
- have appearance
- Printability features
- Low cost
- Compatible with the food
- Special features such as unitizing (oneness) group of products. Together care taken by the food producer to prepare wholesome and attractive food must be matched by the care to select suitable and compatible packaging. (Tamine, 1999)

### 2.4 Packaging requirement for foodstuffs

Before deciding which packaging material might be used, one must have as much information as possible on the packaging requirement of the product, i.e. what hazards will cause product deterioration and the conditions to which the packaged product will be subjected throughout its shelf life. One must also bear in mind that not only the product but the package it self may deteriorate either under the influence of external agencies or attack on it by the product. Each product will of course have its own particular characteristics but the most relevant hazards. To foodstuff are moisture gain or loss, the effect of gases and the effect of light.

Change in moisture content is possibly the most widespread cause of deterioration for foodstuffs and other products. The effect of moisture can range from caking of powdered products and settings of dry ones such as biscuits, to bacterial and mould growth. In order to prevent these situations the packaging material must provide a good water vapour barrier.

Many foods are also susceptible to deterioration from contact with oxygen in the air leading for instance to rancidity and the growth of aerobic bacteria and moulds. Oily products such as potato chips, nut, etc., can become rancid after exposure to oxygen. The very high surface area exposed increases the extent of this problem with such products. Ground coffee also contains oily components and become stale on exposure to oxygen.

In addition to the change of flavour due to chemical reactions, there can be changes from the loss of volatile constituents: this is true for coffee, tea, etc. An important and related, gas barrier requirement arises where a packed product is evacuated or gas flushed to increase the shelf life. Coffee, dried milk and snack foods are examples of this; the gases most commonly used are nitrogen or carbon dioxide.

Many deteriorate reactions proceed more rapidly under the influence of light, so one has to balance a possible marketing requirement for product visibility against the effect of exposure to light or shelf life. (Palling, 1980)

### 2.5 Types of packaging materials

**Metal containers and closures**

Since the introduction of hermetic metal containers for heat processed foods, in the easily the packaging of foods and beverages with metallic materials has progressed and grown into a very large and diverse industry.

**Rigid plastic packaging**

Plastic are the newest of the materials used in food packaging and rigid plastic containers have been used for uneven shorter time than have plastics in the form of films and laminates.

**Flexible plastic packaging**

Historically, flexible materials have been use as long as, or longer than, rigid ones. At first large leaves and skins, then natural materials such as woven fibres, then paper, cellulose film, cellulose acetates and finally the wide range of thermo plastics came into currently use.

There is an extremely large number of material types available, this can be calculated theoretically to run into tens of thousands. Of the dozen or so flexible materials in most common use based on plastics, cellulose, and paper.

Paper and paper board

To summaries the history of paper and paper board would be a fairly formidable task. The flexible and the interaction of paper within the packaging market is vital it the changes that have taken place in the paper industry are to be really appreciated; anyone concerned with development must be vary that he never forgets the chameleon properties and dynamism of this vast international industry.

**Glass**

Glass has been with us for countries. In the early civilizations, it had simple applications, such as drinking vessels, water pitchers, etc. Now it is material that has wide applications in industry and technology. So glass bottle might be seen as a humble product of multi-use material.

**Wood**

It is more expensive than other raw materials. It is inappropriate for high speed packing. It offers good impact strength. Wood may be used in the manufacture of crates that contain fresh fruits and vegetables.(Abstract of packaging institute)

## 2.6 Packaging materials for snack foods

This group includes cereal flakes, vermicelli, chips, extruded snacks, biscuits and crackers. They are sensitive to moisture, as its ingress results in softening and microbial spoilage but below a certain level, become fragile. For snack foods like fried potato and banana chips that contain high surface, fat and low moisture, absorption of moisture and oxygen results in loss of crispness and development of rancidity. Also the staling process takes place. Also most products are highly ready to crush. Some product's are flavoured .If the packaging material has less barrier property loss of flavour volatile or the absorption of undesirable odours. If there is not light barrier property, product can be caused to discolouration.

Table 2.2 Packaging characteristics needed for some commodities

| Commodity | Packaging Characteristics needed | Type of packaging material | Packaging machine |
|---|---|---|---|
| Bakery products | Moderate moisture barrier, grease proof ness for cakes. | LDPE film (bags) | AMF mark 50<br>FMC (form and fill) |
| Biscuits and crackers | Excellent moisture barrier, grease resistance, protection from physical damage | PE bags, LDPE/PE bags. | AMF mark 50 |
| Confectionery | Excellent-poor moisture protection | PE bags, Multi packs | Hayssen , Trans-wrap |
| Snacks | Good odour barrier, moisture protection<br>Good $O_2$ barrier,<br>Good fat barrier,<br>Flavour retention | PE bags, PE laminates, LDPE laminates with film and foil, PE laminates with PP | Woodman, Wright, Hayssen, Mira-pak |

(Sacharow , 1976)

Maize grit (Moisture content 12%) → ← Water

Mix with water ½ hour

(14-14.5% M.C. is required for the process) ↓

Hopper (310-320 r.p.m. Extruded temperature 88$^0$C)

↓

Extruded snacks

↓

Oven (Final moisture content 2.5%)

↓

Flavour coating drum

Flavour unit (Oil + flavour) → ↓

Final product (flavoured snacks)

↓

Collect to the cardboard container and seal them

(It is lined with two polythene bags)

Figure 2.2 Production flow of snack (Tipi tip)

Flavoured snacks

↓

Feeding hopper of

Form-Fill-Seal machine

Packaging material ———— Insert $N_2$ gas

↓

Primary packaging (in to the flexible packaging bag)

↓

Secondary packaging (60 packs in to the 1 corrugated box)

↓

Tertiary packaging

Storage in a warehouse (Stack 8 boxes into 1 column)

↓

Distribution

Figure 2.3 Packaging and distribution of snacks

### 2.7 Climatic variation of Sri Lanka

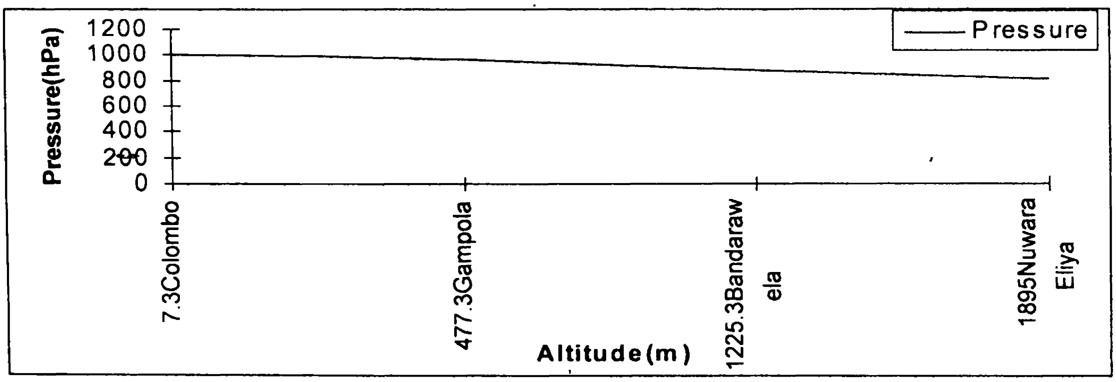



Figure 2.4 Average atmospheric pressure variations with respect to the altitude

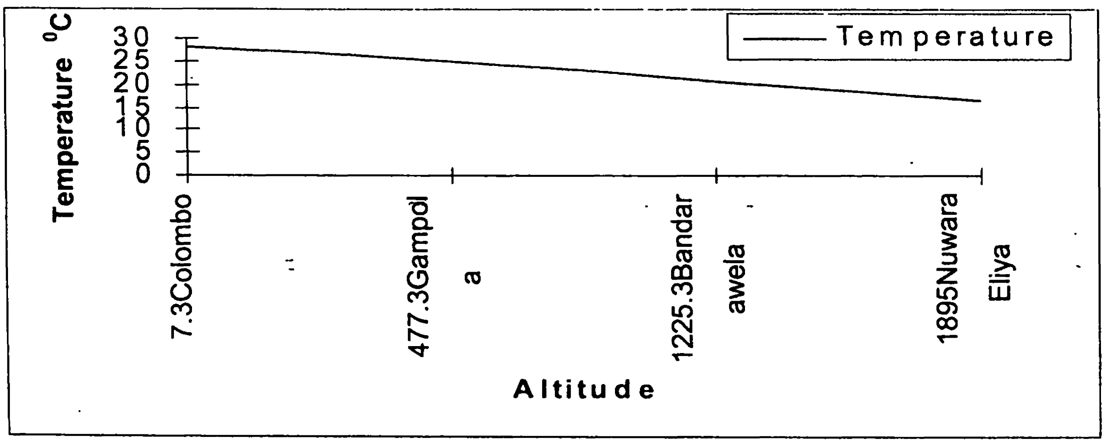



Figure 2.5 Average environmental temperature variations with respect to the altitude (Meteorological abstract and supplements 1997 – 2001)

**2.8 How does the environmental aspects affect on packages?**

In order to design successful packaging four sets of facts must be considered.

1. Product assessment
2. The hazard of distribution
3. Marketing requirement
4. Packaging materials selection and machinery considerations.

Under the hazards of distribution there is a climatic hazards.

Table 2.3 Climatic hazards

| Basic hazard | Typical circumstances |
|---|---|
| High temperature | Direct exposure to sunshine<br>Proximity to broilers, heating systems etc.<br>Indirect exposure to sun in sheds, vehicles etc. with poor insulation.<br>High ambient air temperature. |
| Low temperature | Unheated storage in cool climates<br>Transport in unheated aircraft holds.<br>Cold storage. |
| Low pressure | Change in altitude, particularly in unpressurized aircraft holds-aircraft pressurization failure. |
| Light | Direct sunshine<br>UV exposure<br>Artificial lighting |
| Liquid water | |
| Fresh | Rain during transit, loading and unloading<br>Warehouse and storage<br>Puddles and flooding<br>Condensation and ship sweat, etc. |
| Polluted | Sat sea spray-deck cargo, lightning surfboats, etc.<br>Salt water puddles on docks etc. |
| Dust | Exposure to wind driven particles of sand, dust, grit, etc. |
| Water vapour | Humidity of the atmosphere, both natural and artificial. |

(Paine F.A. & Paine H.Y. ,1992)

## 2.9 Packaging with inside gas

The recognition of the advantages to be gained from the use of gases in order to control the biochemical, enzymatic and microbial changes in perishable foodstuff is not a recent phenomenon.

One can define gas packaging as a method of packaging perishable products in specific gas mixtures, to extend the shelf life of the particular product. Gas packaging is one form of the so-called modified atmosphere packaging technique.

Insert in gas packaging has increased considerably in recent years, and the method is being applied increasingly to various products. The main reasons for this are:

1. an increased consumer demand for high quality products
2. to increase the shelf life
3. to protect from physical damages

On the other hand, gas packaging seems to be a promising alternative for those commodities that are not at all studies to vacuum packaging due to compression and crushing of the products or the risk of mechanical damage to the packaging materials. (Ahrenäinen, 1989)

### 2.9.1 The gases used and their significance

Generally three normal air gases are used either alone or as mixtures in gas packaging: nitrogen, oxygen and carbon dioxide.

**Nitrogen**

Nitrogen has two roles in gas packaging; first, it displaces oxygen. If the products need protection only against oxidation and rancidity, as is the case with dried products and powders it is advantage to use single gas flushing with nitrogen. Nitrogen is preferred to carbon dioxide in this context, because unlike $CO_2$ it does not dissolve into the fatty tissue of the food. With regard to moist foods, displacement of oxygen by nitrogen retards the growth of aerobic bacteria, yeast and mould, the oxidation of fats and colours and the development of off-flavour. Nitrogen itself is inserted and does not interact with micro organisms.

Nitrogen's second role in gas packaging is to act as inner filler, which keeps flexible packages from developing vacuum. This is a problem particularly with moist food products packed in carbon dioxide.

**Oxygen**

As a role, the aim in gas packaging is to reduce the oxygen concentration in the head space of a package below1-2%, ever to 0.2% by replacing oxygen with nitrogen/ or carbon dioxide. On the other hand anaerobic microbes are not able to grow to a great extent in an atmosphere containing 1-2% oxygen. In some cases, however, oxygen has to be used in a gas mixture. The use of oxygen is also recommended to product the growth of food poisoning anaerobic micro organisms.

**Carbon dioxide**

In order to extend the shelf life of foodstuff by retarding microbial spoilage, carbon dioxide is used either alone or with nitrogen or/and oxygen. Concentration of $CO_2$ above about 5% inhibits the growth of a broad spectrum of food spoilage bacteria, yeast and moulds. The effect of $CO_2$ on the growth of micro organisms is depending on:

- The concentration of the carbon dioxide
- The temperature
- The water activity of the food or the medium.

(Ahvenainen, 1989)

Also $CO_2$ is readily soluble in both water and any lipid component within the pack must be recognised in setting the initial gas composition. If $CO_2$ on its own is used in a pack then, with a moist or/and fatty snack, a partial vacuum eventually forms and due allowance must be made to prevent collapse of the primary pack. Mixing carbon dioxide with nitrogen reduces the effects of dissolution into the food components. Conversely, if it is known that packs are to be delivered to a geographic region several thousand feet above sea level, then $CO_2$ partially dissolve in the food components prevents pack failure caused by the lower external pressure on the pack. (Booth, 1997)

## 2.10 Packaging material properties needed for gas packaging

With regard to the microbial and sensory shelf life and quality of gas packed foodstuffs, appropriate packaging materials are more important than the type of the packaging machine, although the packaging technique also affects in particular the appearance of a product; e.g. a vacuum before gas flushing cannot be used for more some products due to crushing and compression, as has already been mentioned. Several factors must be taken into account in determining the combination of packaging material properties required for each specific product and market. Particularly with regard to gas packaging, the important factors are the following;

### 2.10.1 The barrier properties needed

In most gas packaging applications, excluding vegetables and fruits, it is desirable to maintain the atmosphere initially injected into the package for as long a period as possible. The correct atmosphere at the start will not serve for long if the packaging materials allow it to change too rapidly. Some of the polymers currently used include PE, PETP, metalized PEPT, PP, PS, PVC, PVDC, PA, EVA and EVOH. Their oxygen and water vapour permeability are given in table 2.4 .There polymers are normally used as laminated or co-extruded multilayer materials in order to have the barrier properties required. The inner layer is usually polyethylene or its co- polymer which forms the food contact and heat seal medium. Polyethylene or ethylene vinyl acetate alone is not suitable for gas packaging because of their high gas permeability.

Table 2.4 Water vapour permeability and oxygen permeability.

| Polymer | Oxygen permeability $Cm^3$, 24h, 101.3kPa, $23^0C$, 75%RH | Water vapour permeability (g/m3, 24h) $38^0C$, 90% RH |
|---|---|---|
| PVDC | 0.31 | 0.31 |
| PA 66 | 31 | 93-155 ($40^0C$) |
| OPA 6 | 18.6 | 155 |
| PP | 2325 | 3.9-10.9 |
| PET | 74.4-139.5 | 27.9-46.5 |
| PVC (rigid) | 77.5-310 | 14.0-79.1 |
| HDPE | 2335 | 15.5-23.3 |
| LDPE | 6510 | 108.5-170.5 |
| PS | 5425 | 108.5-170.5 |

Source - Ahvenainen, 1989

**2.10.2 Mechanical strength**

In choosing packaging materials for gas packaging one has also to pay attention to how resistant to mechanical stress (e.g. puncture), humidity and temperature (frozen or chilled) the material needs to be. If a material is of poor mechanical strength, the mechanical stresses, humidity and low temperature during storage, transport and handling and damage the package and cause leakage.

**2.10.3 Integrity of sealing**

The adequate integrity of the seal is important in order to maintain the correct atmosphere in the package. The seal, however, must not be too tight; the right balance between tightness and security of the closure and ability to peel back a lidding material must be determined.

**2.10.4 Type of package**

The type of package to be used; rigid or semi rigid lidded tray or flexible film pouch, has to be taken into consideration when choosing packaging materials.

**2.10.5 Fogging**

In order to improve the appearance of the packages in retail outlets the polyethylene in the packaging laminates can be especially treated to prevent condensation of water, which fogs the package and prevent the consumer examining the product. ( Ahvenainen, 1989)

### 2.11 Types of packaging Machines for gas packaging

There are eight different types of basic packaging systems used for gas packaging.

1. Horizontal form- fill – seal machines
2. Vertical form - fill - seal machines
3. Vacuum chamber machines
4. Gemella packaging system
5. Fibrelam system
6. Bay in carton system
7. Bay in box system
8. Walki-vent system

(Ahvenainen , 1989 )

#### 2.11.1 Vertical form-fill-seal machines

Several types of vertical machines are in commercial used including those that form a 3 – side pillow – pouch package and those that form a four side face to face seal pouch. Four side seal pouches may be formed from to webs of material as on a circle machine used for liquids and dry products.

The pillow – pouch is generally constructed with two end seals and a back or side seal running the length of the pouch. The end seals are face to face but the long seam may be overlap or face to face (usually called fin).

In almost all the commercial equipment vertical form fill and seal, three side seal pouches are formed by drawing that flexible packaging material from a roll. Cellophane, Cellophane lamination, Polyethylene or lightweight flexible aluminium foil lamination are common vertical form fill and seal materials.

The flexible material is drawn over and around a collar that is usually above a cylindrical tube. Heat-sealing usually against the tube forms a long seam. A horizontal draw bar then pulls the material the length of a pouch, simultaneously forming the top end seal of the next succeeding pouch. Cut-off may be at this point by the action of knife in the heat seal bars, or may be by a separate cutter beneath the heat-sealing site. After the bottom end seal is formed and the draw bar is moving up , product drop from the filler in to the newly formed open – top pouch.

There are how ever numerous variations that differentiate the equipment and make the package developer's task more interesting, since these variations are not always widely known. For example, Hayssen machinery can employ power driven rolls to assist the draw bar in pulling flexible materials from the roll

### 2.11.2 Horizontal form-fill-seal machines

Horizontal flexible packaging equipment forms the package while the film is travelling in a horizontal plane. Product may be filled from either the horizontal or vertical direction. Because face-to-face seals are made on all four sides, both liquid and moisture sensitive products such as dry soups, beverage mixes etc. can be enclosed.
(Griffin & Sacharow, 1978)

## 2.12 Flexible packaging

Materials used in flexible packaging

ABS- Acrylonitrile butadiene styrene
EVA- Ethylene Vinyl Acetate
EVAl- Ethylene Vinyl Alcohol
HDPE-High Density Poly Ethylene
LDPE-Low Density Poly Ethylene
MS-Nitro Cellulose Coated Cellulose Film
MXDT-One Side PVdC Coated Cellulose Film
MXXT-Two Side PVdC Coated Cellulose Film
OPP-Oriented Poly Propylene
OPS-Oriented Poly Styrene
PA-Polyamide
PBTP-Poly (Butylene Terephthalate)
PCTFE- Poly Chloro Tri Fluro Ethylene
PE-Poly Ethylene
PET-Polyester
PETP-Poly (Ethylene Terephthalate)
PP-Polypropylene
PS-Polystyrene
PVAl-Polyvinyl Alcohol
PVC-Polyvinylchloride
SAN-Styrene Acrylonitrile
UPVC-Unplasticised Poly (Vinyl Chloride)
EAA-Ethylene Acrylic Acid

### 2.12.1 Basic Films

**Polyolefims**

They have generally similar properties, being extensible, heat sealable and good water vapour but poor gas barriers. Polyethylene has been the most widely used material, mainly in its low density form. LDPE has low melting point with high heat sealability. Also HDPE has high melting point and low heat sealability.

**Copolymers**

As the name suggested these differ from the homo polymers in that they are formed by the copolymerisation of two dissimilar molecules.

-Ethylene Vinyl Alcohol

A material with extremely good gas barrier properties, moved unfortunately by a high sensitivity to water vapour

-Vinylidene Chloride-Vinyl Chloride

A Copolymer which is used as a self supporting film in order to utilise the very high barrier performance that poly (Vinylidene) can provide, but which is not suitable for use as a straight film.

**Other plastics**

-PolyVinyl Chloride

It is used in two distinct forms.

1. Unplasticised- Rigid material for thermoforming

2. Plasticised - Very flexible, high transparent and with pronounced blocking tendencies, with high gas permeability characteristics. Specially suitable for cling or stretch wrap applications.

-Polystyrene

Used as a thermoformable sheet in food packaging. Theroformable sheet material is normally modified by the incorporation of synthetic rubber compounds to improve the impact resistance. It is very permeable to water vapour and moderately so to gases.

-Polyamides

Good gas barrier performance, grease resistance and mechanical strength are very useful. Resistance to higher temperatures than most other common plastics. The polyamides are rather moisture sensitive and quite permeable to water vapour, hence their major form of use is as a co-extrusion with Low Density Polyethylene, thus both protecting the nylon and providing the barrier to water vapour.

-Polystyrene

The materials have high mechanical strength and stability and have barrier properties similar to the polyamides.

-Acrylonitriles

These have very high gas barrier properties and have been used in sheet form for thermoforming.

**Modified Cellulosics**

Derived from naturally occurring cellulose, are chemically modified in to true thermoplastics. The major areas of applications are thermoformed blisters, window and for cartons and rigid transparent cartons.

**Regenerated Cellulose**

These films are made from selected wood chips in which the cellulose is taken into solution and reprecipitated as a continuous transparent film. The basic material is an excellent barrier to gases, but is sensitive to, and very permeable to water vapour.

**Non-Plastics**

Materials used in combination with plastics for food packaging include paper in a wide range of types and aluminium foil. The former contributes stiffness and printability; the later provides an almost perfect barrier to gases and light. Both provide folding properties and rigidity.

(Palling, 1980)

**2.13 Film manufacture**

All of the thermoplastics are formed into sheet or film by the basic process of screw extrusion. The basic components of the extruder is shown feeding a slot die in figure 2.6

1. Input hopper-granules
2. Feeder screw
3. Heating element
4. Slot extrusion die
5. Extruded film

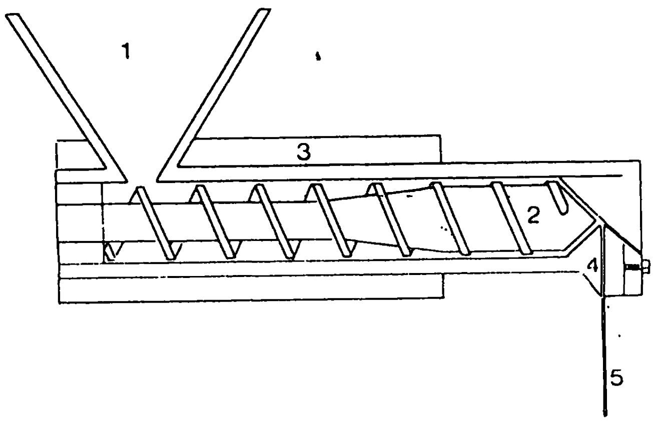



Figure 2.6 Basic components of the extruder

By using combining adaptors to extrude simultaneously two or three different polymers that fuse at the point of film formation into a single web. This is the 'co-extrusion' process and it can be used with either slot dies or circular types. The components of the extruder are shown in figure 2.7

a- hopper material a

b- hopper material b

c- hopper material c

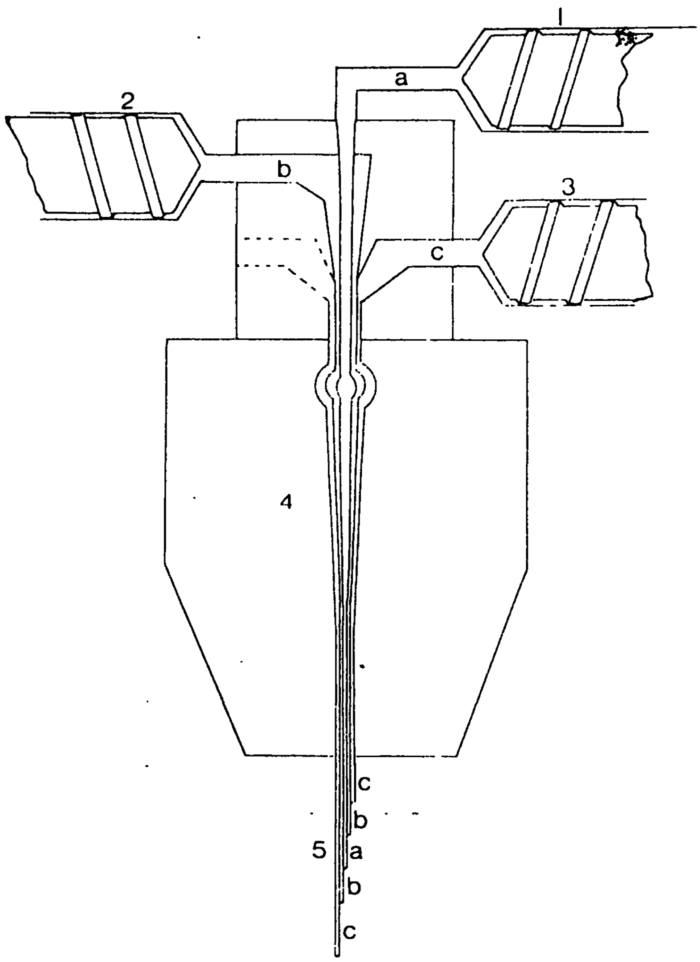



Figure 2.7 Multilayer extruder

## 2.14 Multilayer packaging

Simply combinations of different layers / films on different polymers are processed by extrusion process or lamination process.

1. Lamination - Wet bond lamination
   - Dry bond lamination
   - Wax lamination
   - Thermal or pressure lamination
2. Extrusion coating
3. Extrusion lamination

### 2.14.1 Wet bond lamination

Any processes where liquid adhesive is applied to substrate that is then immediately combined with a second ply to create a laminate. The adhesive is water born one of the webs must be permeable (or porous) to the solvent vapour. Laminated film can be delaminated.

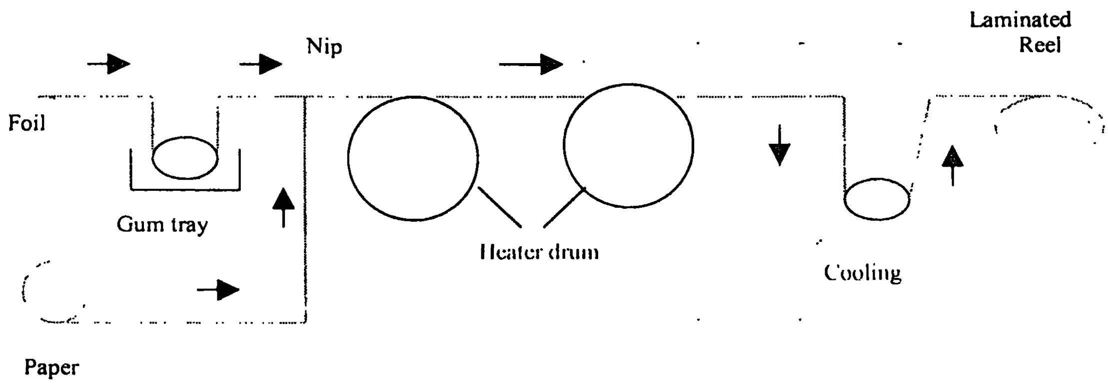



Figure 2.8 wet bond lamination process

### 2.14.2 Dry bond lamination

Solvent born adhesive is applied to a substrate that passes through a drier to evaporate the carrier solvent. The web is then combined with a second substrate in a heated pressure nip. Laminated film can be de laminated.

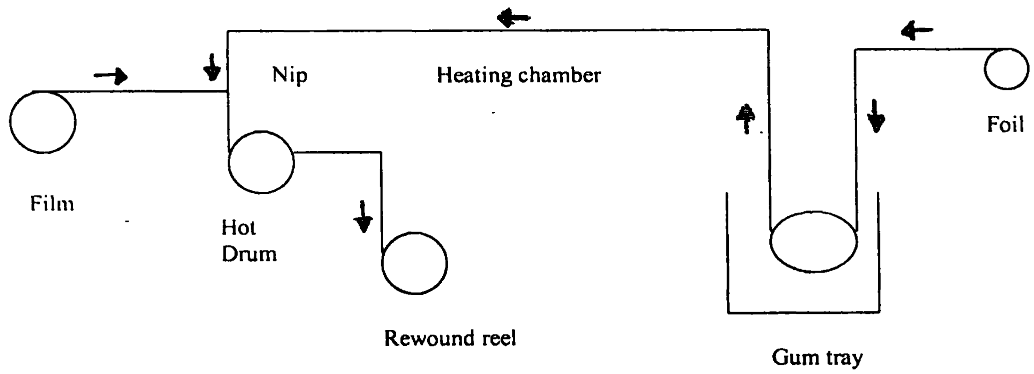



Figure 2.9 Dry bond lamination process

### 2.14.3 Thermal or pressure lamination

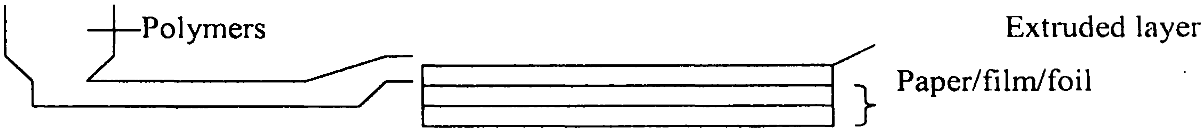
It is difficult to separate some thermal bonding from dry bonding. Previously applied thermoplastic adhesives, which are activated by the heat and pressure of the thermal laminating is called thermal or pressure lamination. Laminated film can be delaminated.

### 2.14.4 Wax lamination

Bonding of paper-to-paper, paper to board or paper to foil with a continuous Wax film. Micro waxes, which, may be blended with paraffin wax, are used as the bonding agent. Sometimes special resins are added to improve adhesion. Laminated film can be delaminated.

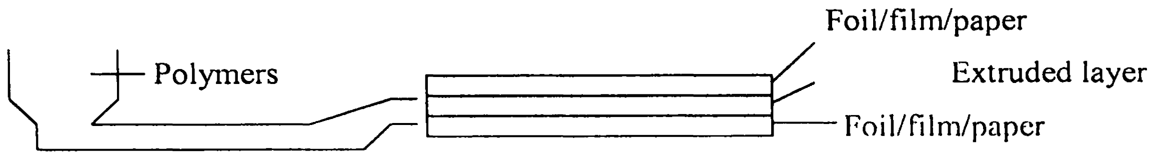
### 2.14.5 Extrusion coating

Extrusion coating is a process in which an extruder force melted thermoplastic. through horizontal slot die into moving web material the rate of application control the thickness of the continuous film deposited on the surface of the paper board, film or foil. The melt stream extruded in one or several layers can be used as a coating or as an adhesive to sandwich two webs together. This foil can't be delaminated.




### 2.14.6 Extrusion lamination

In extrusion laminating a film of molten polymer is deposited between two moving webs in a nip created by a rubber pressure roll and a Chrome plated steel chill roll. In this continuous operation chemical priming or other surface treatment to make it receptive to the extrusion coating and to help develop adhesion between the two materials prepares the surface of the substrate. This foil can't be delaminated.




(Abstract of packaging institute)

### 2.15 Packagė development

Packaging has both immediate and long- range influences on sales and profits. Immediate influences are those that persuade impulse or first purchase buying. Long range influences are those that convince the purchaser to re buy the product because of a convenience of feature or a quality feature. Regardless of the organizational arrangement the packaging development department has a number of important responsibilities.

1. To be aware of existing and new packaging materials and have a general knowledge of their properties and cost.
2. To be aware of marketing and technological developments that create new packaging requirements and make old ones obsolete.
3. To be aware of competitive packaging, its composition and economics, advantages, and disadvantages.
4. To develop short-range packaging modifications that will reduce costs, improve product shelf life, increase product turn over, improve product acceptance, or help introduce new product.
5. To develop long range packaging programs, which promote the corporate image. Coordinate a line of products, reduce waste, extend market areas or expand into new markets.
6. To develop new packaging innovations.
7. To be aware of available packaging machinery and its capabilities.

8. Develop complete packaging systems, which integrate the package, product and equipment needs.

The amount of effort expended in a development project in packaging depends upon the type of development required. There are several types, which may be categorized as follows.

1. The modification of an existing packaging for an existing product in order to improve sales through:
   a. Improved aesthetics of package design
   b. Improved price due to lower cost materials, improved manufacturing efficiencies, or improved performance in handling, distribution and storage.
   c. Improved product quality due to improved package protection
   d. Improved product utility due to improved package performance and convenience features.
2. Expansion of a product line through use of a well- tried and proven package that has been used for:
   a. Similar products or
   b. Radically different products, but can be adapted to the proposed use.
3. Development of a new package concept for a proven product to improve sales through:
   a. Revised customer interest
   b. Improved product quality
   c. Improve product utility
4. Development of a new package concept for a new and untried product

(Palling, 1980)

## 2.16 Economics of packaging

Economics can be defined as the science of production and distribution of resources. Packaging material and containers are included under the resources heading. They concern not only the production and distribution but also the sealing of product. The surface design or package shape can have a significance effect on sales. For an industrial product, however, the identification and physical protection provide by the pack are the critical factors. Cost but also by its effective contribution to the whole operations. The actual unite packaging material cost as a percentage of the total. (Tamine, 1999)

## 2.17 Problems encountered in food packaging

Whilst many technological problems encountered in the use of plastics for food packaging applications are those that are common to packaging industry as a whole, some other considerations arise solely though the nature of the product to be packaged. Most foods are perishable, having a useful life, which can be as short as only a day or two in the case of some fresh foods, depending on the conditions of storage. Hence, requirements for a food packaging materials are generally more stringent than for many other retail and household commodities. The principal intrinsic requirements of a food packaging material can be classified as follows:

1. Transparency and surface gloss for customer appeal.
2. Control over transfer of moisture
3. Control over transfer of other gases/ vapours.
4. Wide temperature range in storage and use.
5. No toxic constituents
6. Low cost
7. Protection against crushing

Customer likes to see what they are buying and, hence transparency is essential requirement in many foods packaging applications. Control over changes in the moisture content of a food during storage is most important. Some products, e,g. snack foods, biscuits or boiled sweets, must be packed in a material with a very low permeability to water vapour to preserve crispness.

In other cases, some loss of moisture is desirable to avoid sweating, condensation on the inside of the package and concomitant loss of transparency as well as increased risk of mould growth. Control over permeability to other gases such as oxygen and carbon dioxide is also very important.

Most fresh foods need to "breathe" hence the packaging material used for these products must allow ingress of oxygen and respiration of carbon dioxide. On the other hand, foods with a high fat content become rancid on exposure to oxygen Fresh Meat also requires ingress of oxygen to maintain a satisfactory surface colour.

Low permeability materials are also useful for the packaging of fish, coffee where the odour must be contained strictly with in the package. Some products are delicate e.g. cereals and crisps and need to be loosely packed. This increases the air inside the package and coupled with the high surface area of such product can lead to rancidity.

Production cost varies according to the product type. For commodity food product such as sugar and flour, it is usually below 5percent. For other consumer products such as detergent, toilet soaps and biscuits the figure varies between 5 percent and 10 percent. In the areas of toiletries and cosmetic products the packaging cost is often equal to or greater than that of the product itself.

There is no direct relation between product and packaging price. For example, expensive items such as electrical appliance are often packaged at a cost of less than 5% of the total production cost. Cost consideration plays a major role in the work of all the people concerned with packaging operations. (Crosby, 1981)

# CHAPTER 3

# Materials & Method

## 3.1 Materials

### 3.1.1 Effect of pressure gradient on final properties of the package.

Existing packing material types in the institute.

1. PET / PE / CO+POLYMER / ALU / PE – Strong Pack (SP)
2. PET / INK / PE / ALU / EAA – Flexi Pack (FP)
3. PET / EXTN POLY / AL FOIL / EXTN POLY – N – Flex Industries Pack (IP)

Flavoured Green onion flowers (Snacks)

$N_2$ Gas.

### 3.1.2 Effect of the environmental temperature on final properties of the package

Existing packing material types in the institute. (Above mentioned)

Flavoured Green onion flowers (Snacks)

Nitrogen gas.

Ice bath

Refrigerator

Thermometer

Hot water bath

### 3.1.3 Effect of vertical sealing temperature on vertical seal of the package.

Existing packing material types in the institute. (Above mentioned)

Nitrogen gas.

### 3.1.4 Effect of anti-wrinkling and anti-blocking powder application of the film on vertical seal.

Existing packing material types in the institute. (Above mentioned)

Nitrogen gas.

Two pieces of sponge

### 3.1.5 Effect of internal gas composition on package bursting.

#### 3.1.5.1 Internal gas composition without gas absorbent.

Existing packing material types in the company (Above mentioned)

Flavoured Green onion flowers (Snacks)
Nitrogen gas.
$CO_2$ Gas

**3.1.5.2 Internal gas composition with gas absorbent.**

Existing packing material types in the institute. (Above mentioned)
Flavoured Green onion flowers (Snacks)
$CO_2$ Gas
$CO_2$ Gas absorbent –$CaCl_2$ (Food grade Calcium chloride)

**3.1.6 Effect of the placing pattern of vertical seal (fin) on package bursting.**

Existing packing material types in the company (Above mentioned)
Flavoured Green onion Flowers (Snacks)
Nitrogen gas.

**3.2 Method**

**3.2.1 Effect of pressure gradient on final properties of the package.**

Samples were selected from simple random sampling method from different batches with different packaging materials as follows.

e.g. Colombo

| Packaging material type | SP | FP | IP |
|---|---|---|---|
| No of sample | 32 | 32 | 32 |

They were kept for certain time (2 month) in different geographical areas. (Different environmental conditions) These areas were given Table 3.1.

Table 3.1 Areas were used for this project

| Area | Altitude (m) | Pressure (hPa) | Temperature ($^0$C) |
|---|---|---|---|
| Colombo | 7.3 | 1009 | 28 |
| Gampola | 477 | 957 | 25 |
| Bandarawela | 1225 | 877 | 21 |
| Nuwara Eliya | 1895 | 813 | 16.5 |

### 3.2.2 Effect of the environmental temperature on final properties of the package.

Samples were selected from simple random sampling method from different batches with different packaging materials as follows.

e.g. Colombo

| Temperatures $^0C$ | No. of samples | | |
|---|---|---|---|
| | SP | FP | IP |
| 5 | 5 | 5 | 5 |
| 10 | 5 | 5 | 5 |
| 15 | 5 | 5 | 5 |
| 20 | 5 | 5 | 5 |
| 25 | 5 | 5 | 5 |
| 30 | 5 | 5 | 5 |
| 35 | 5 | 5 | 5 |
| 40 | 5 | 5 | 5 |

They were kept in different temperatures for certain time (24 hours) using refrigerator, ice bath and hot water bath as follows.

| Temperatures $^0C$ | Equipment |
|---|---|
| 0 | Freezer |
| 5 | Ice bath |
| 10 | Ice bath |
| 15 | Ice bath |
| 20 | Ice bath |
| 25 | Air condition chamber |
| 30 | Hot water bath |
| 35 | Hot water bath |
| 40 | Hot water bath |

Visible readings were recorded according to the given scale.

0 – pack was burst

1 – pack was not burst

### 3.2.3 Effect of vertical sealing temperature on vertical seal of the package.

Samples were prepared without product with changing the vertical sealing temperature as follows.

e.g. Colombo

| Packaging materials | Vertical sealing temperatures $^0C$ | | | | |
|---|---|---|---|---|---|
| | 150 | 155 | 160 | 165 | 170 |
| SP | 10 | 10 | 10 | 10 | 10 |
| FP | 10 | 10 | 10 | 10 | 10 |
| IP | 10 | 10 | 10 | 10 | 10 |

Samples were kept certain time in Colombo, Gampola, Bandarawela, Nuwara Eliya.

Standard vertical sealing temperatures of different packaging materials were given below Table 3.2. That was mentioned in their raw material specifications.

Table 3.2 Standard vertical sealing temperatures of the different packing materials

| Packaging materials | Normal vertical sealing Temperatures $^0C$ | Normal front jaw sealing temperatures $^0C$ | Normal rear jaw sealing temperatures $^0C$ |
|---|---|---|---|
| SP | 160 | 170 | 170 |
| FP | 160 | 170 | 170 |
| IP | 160 | 170 | 170 |

### 3.2.4 Effect of anti-wrinkling and anti-blocking power application of the film on vertical seal.

A set of samples was prepared after rinsing the two vertical sealing surfaces (edges of the packing material) to remove the powder application by using sponges. (Figure 3.1)

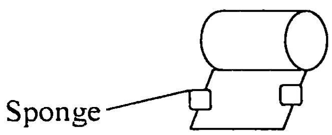



Figure 3.1 Method of rinsing the powder application

Another set of samples was prepared without rinsing the powder application.

e.g. Colombo

| Type | Colombo | Gampola | Bandarawela | Nuwara Eliya |
|---|---|---|---|---|
| With powder application | 10 | 10 | 10 | 10 |
| Without powder application | 10 | .10 | 10 | 10 |

These samples were kept in certain time in different areas.

### 3.2.5 Effect of internal gas composition on package bursting

#### 3.2.5.1 Internal gas composition without gas absorbent.

First set of samples was prepared flushing $N_2$ gas at a pressure .6 bar.

Second set of samples was prepared flushing $CO_2$ gas at a pressure .6 bar.

Third set of samples was prepared flushing both $N_2$ and $CO_2$. Both were flushed at a pressure .6 bar at once.

e.g. Colombo

| Gases | Packing material types | | |
|---|---|---|---|
| | SP | FP | IP |
| $N_2$ | 10 | 10 | 10 |
| $N_2 + CO_2$ | 10 | 10 | 10 |
| $CO_2$ | 10 | 10 | 10 |

These samples were kept certain time in different areas.

Volume reduction rate was calculated.(See chapter 2.9.1 )It is similar to the $CO_2$ absorption rate by the product. Also environmental temperature of different areas affects on the $CO_2$ absorption rate was observed. Also bursting percentages of the packs with different gas composition were calculated and find out the best internal gas with less bursting percentage.

Sensory evaluation test was conducted to check the $CO_2$ affects on colour and taste of the snacks.

For sensory evaluation test;

Reference sample No.- 183

Sample No of the snacks, which $CO_2$ was flushed – 235

Sample No of the snacks, which $N_2$ was flushed – 852

For the ballot paper see Appendix 1

#### 3.2.5.2 Internal gas composition without gas absorbent

To increase the $CO_2$ absorption rate within the pack gas absorbent was used. To the small polyethylene bag food grade calcium chloride ($CaCl_2$) was input and sealed them. When preparing samples these $CaCl_2$ bags were inserted. $CO_2$ absorption rate was calculated.

Samples were kept certain environmental conditions and bursting percentages were calculated with respect to the relevant area.

e.g. Colombo

| Packaging material type | $CaCl_2$ (g) | | | |
|---|---|---|---|---|
| | .5 | 1 | 1.5 | 2 |
| SP | 2 | 2 | 2 | 2 |
| FP | 2 | 2 | 2 | 2 |
| IP | 2 | 2 | 2 | 2 |

**3.2.6 Effect of the placing pattern of vertical seal (fin) on package bursting.**

Set of samples was prepared in normal way. Another set of samples was prepared after forming the packs vertical seal (fin) was turned into oppersite side from the normal pattern. (figure 3.2 ) These samples were kept in certain time in different areas and checked the bursting places.

Figure 3.2 Placing patterns of the vertical seal (fin) is on the package

a. fin is on left side

b. fin is on right side

a b

# CHAPTER 4

## Results and Discussion

### 4.1 Results

### 4.1.1 Effect of the pressure gradient on final properties of the package

Table 4.1 Percentages of the package bursting under the different pressure conditions. (Different areas)

| Packing material types | Colombo 1009hPa Bursting % | Gampola 957hPa Bursting % | Bandarawela 877hPa Bursting % | Nuwara Eliya 813hPa Bursting % |
|---|---|---|---|---|
| SP | 34.375 | 81.25 | 81.25 | 84.375 |
| FP | 6.25 | 3.125 | 21.875 | 21.875 |
| IP | 6.25 | 12.5 | 28.125 | 34.375 |

Above results were analyzed using the SAS system

$H_0$ : Pressure gradient does not affect on package bursting

$H_1$ : Pressure gradient affects on package bursting

P = 0.0488, So $P < 0.05$

Reject $H_0$ at 5% significance different level.

So, Pressure gradient does not affect on package bursting

$H_0$ : All the packing materials are same

$H_1$ : At least one packing material is different from others

P = 0.0007, So $P < 0.05$

Reject $H_0$ at 5% significance different level.

So, at least one packaging material type is different from others.

According to the mean separation packing material type 1 (SP) is different from others. (See Appendix 2)

Places of gas out from the pack

1. Breaking from the vertical seal (V)
2. Through the cracks on vertical seal (C)
3. Through the hole puncher (H)
4. From the packaging material damages (M) (when handling and forming)

Table 4.2 Bursting percentages according to the damage place.

| Packing material types | V | C | H | M |
|---|---|---|---|---|
| SP | 78.89 | 15.56 | 5.56 | 0 |
| FP | 41.18 | 0 | 29.42 | 29.42 |
| IP | 26.93 | 0 | 65.39 | 7.69 |

Above results were analyzed using the SAS system

$H_0$ : All damage places have same bursting percentage

$H_1$ : At least one damage place has different bursting percentage

P = 0.0059, So P < 0.05

Reject $H_0$ at 5% significant difference level.

So, at least one damage place is different from others.

According to the mean separation damage place 1 (V) has higher bursting percentage. That means most of the packs burst out the gas from the vertical seal.(See Appendix 2)

**4.1.2 Effect of the environmental temperature on the final properties of the package**

Table 4.3 Mean value of the burst packs under the different temperatures

| Temperature $^0C$ | Mean of burst packs | | |
|---|---|---|---|
| | SP | FP | IP |
| 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 |
| 30 | 0 | 0 | 0 |
| 35 | 0 | 0 | 0 |
| 40 | 0 | 0 | 0 |

Above results were analyzed using Minitab.

$H_0$ : Environmental temperature does not effect on package bursting

$H_1$ : Environmental temperature affects on package bursting

P = 1.000 (adjusted for ties), So P > 0.05

Reject $H_1$ at 5% significant difference level.

So, environmental temperature does not affect on package bursting. (See Appendix 3)

### 4.1.3 Effect of vertical sealing temperature on vertical seal of the package

Table 4.4 Bursting percentages of the packs with different vertical sealing temperatures.

| Packaging material type | Area | Vertical sealing temperature $^{0}C$(Bursting %) | | | | |
|---|---|---|---|---|---|---|
| | | 150 | 155 | 160 | 165 | 170 |
| SP | Colombo | 10 | 10 | 10 | 0 | 10 |
| | Gampola | 10 | 10 | 10 | 10 | 20 |
| | Bandarawela | 20 | 30 | 20 | 20 | 20 |
| | Nuwara Eliya | 30 | 20 | 30 | 30 | 40 |
| FP | Colombo | 0 | 10 | 0 | 0 | 0 |
| | Gampola | 0 | 10 | 0 | 10 | 0 |
| | Bandarawela | 10 | 10 | 10 | 0 | 10 |
| | Nuwara Eliya | 10 | 20 | 0 | 10 | 20 |
| IP | Colombo | 0 | 0 | 0 | 10 | 0 |
| | Gampola | 10 | 10 | 0 | 0 | 20 |
| | Bandarawela | 10 | 10 | 10 | 20 | 10 |
| | Nuwara Eliya | 10 | 10 | 20 | 10 | 20 |

Above results were analysed using SAS systems

$H_0$: All temperature conditions are same

$H_1$: At least one temperature level is different from others

$P = 0.1938$, So $P > 0.05$

Reject $H_1$ at 5% significant difference level

Vertical sealing temperatures do not affect on package bursting. (See Appendix 4)

### 4.1.4 Effect of anti-wrinkling and anti-blocking powder application of the film on vertical seal

Table 4.5 No. of burst packs with and without powder application

| Type | Colombo | Gampola | Bandarawela. | Nuwara Eliya |
|---|---|---|---|---|
| With powder application($\mu_1$) | 0 | 1 | 1 | 2 |
| Without powder application($\mu_2$) | 1 | 1 | 1 | 2 |

Above results were analysed using Minitab

$H_0$: $\mu_1 = \mu_2$

$H_1$: $\mu_1 \neq \mu_2$

P = 0.7389 (adjusted for ties), So P > 0.05

Reject $H_1$ at 5% significance difference level

Bursting percentages of two samples are same. Powder application does not affect on package bursting. That means it does not affect on vertical seal. (See Appendix 5)

#### 4.1.5.1 Effect of internal gas composition on package bursting without gas absorbent

Table 4.6 Bursting percentages with different gas composition without gas absorbent

| Area | Packaging material | Bursting % | | |
|---|---|---|---|---|
| | type | $N_2$ | $N_2 + CO_2$ | $CO_2$ |
| Colombo | SP | 33.34 | 13.33 | 13.33 |
| | FP | 0 | 0 | 0 |
| | IP | 6.67 | 0 | 0 |
| Gampola | SP | 80 | 46.67 | 40 |
| | FP | 6.67 | 6.67 | 0 |
| | IP | 6.67 | 0 | 0 |
| Bandarawela | SP | 80 | 53.33 | 46.67 |
| | FP | 13.33 | 6.67 | 6.67 |
| | IP | 20 | 13.33 | 6.67 |
| Nuwara Eliya | SP | 86.67 | 66.67 | 46.67 |
| | FP | 20 | 20 | 13.33 |
| | IP | 33.33 | 20 | 20 |

Above results analysed using SAS system

$H_0$: All gases are same

$H_1$: At least one gas is different from others

P = 0.0014 , So P < 0.05

Reject $H_0$ at 5% significant difference level

So at least one gas is different from others. According to the mean separation gas 1 ($N_2$) is different from others. That means packs that $N_2$ gas was flushed has higher bursting percentage. $CO_2$ absorption rates of different areas were observed. (See Appendix 6)

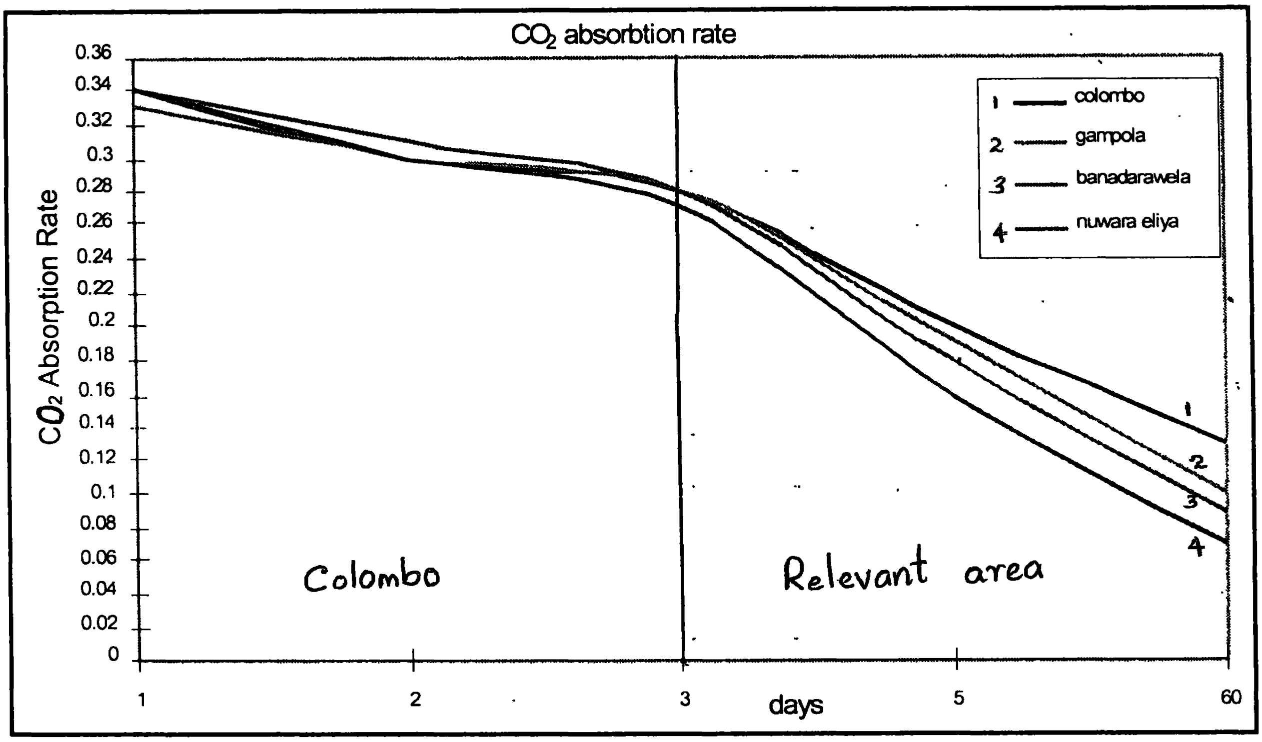



Figure 4.1 $CO_2$ absorption rate of different areas (ml/day)

$CO_2$ absorption rate was higher in Colombo and lower in Nuwara Eliya.

**Results of sensory evaluation test**

Analyse using SAS system

For Colour

$H_0$: There is no difference of the colour

$H_1$: There is a difference of the colour

P = 0.509 (adjusted for ties), So P > 0.05

Reject $H_1$ at 5% significant difference level

There is no difference of the colour. Colour of the reference sample and other two test samples is same.

For Taste

$H_0$: There is no difference of the taste

$H_1$: There is a difference of the taste

P = 0.295 (adjusted for ties), So P > 0.05

Reject $H_1$ at 5% significant difference level. There is no difference of the taste. Taste of the reference sample and other two test samples is same. (See Appendix 6)

#### 4.1.5.2 Internal gas composition with gas absorbent.

Table 4.7 No. of burst packs of internal gas is $CO_2$ with and without gas absorbent

| Type | Colombo | | | Gampola | | | Bandarawela | | | Nuwara Eliya | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| With | SP | FP | IP | SP | FP | IP | SP | FP | IP | SP | FP | IP |
| absorbent($\mu_1$) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Without | SP | FP | IP | SP | FP | IP | SP | FP | IP | SP | FP | IP |
| absorbent($\mu_1$) | 1 | 0 | 0 | 2 | 1 | 1 | 2 | 1 | 1 | 3 | 2 | 2 |

Above results were analysed using Minitab

$H_0$: $\mu_1 = \mu_2$

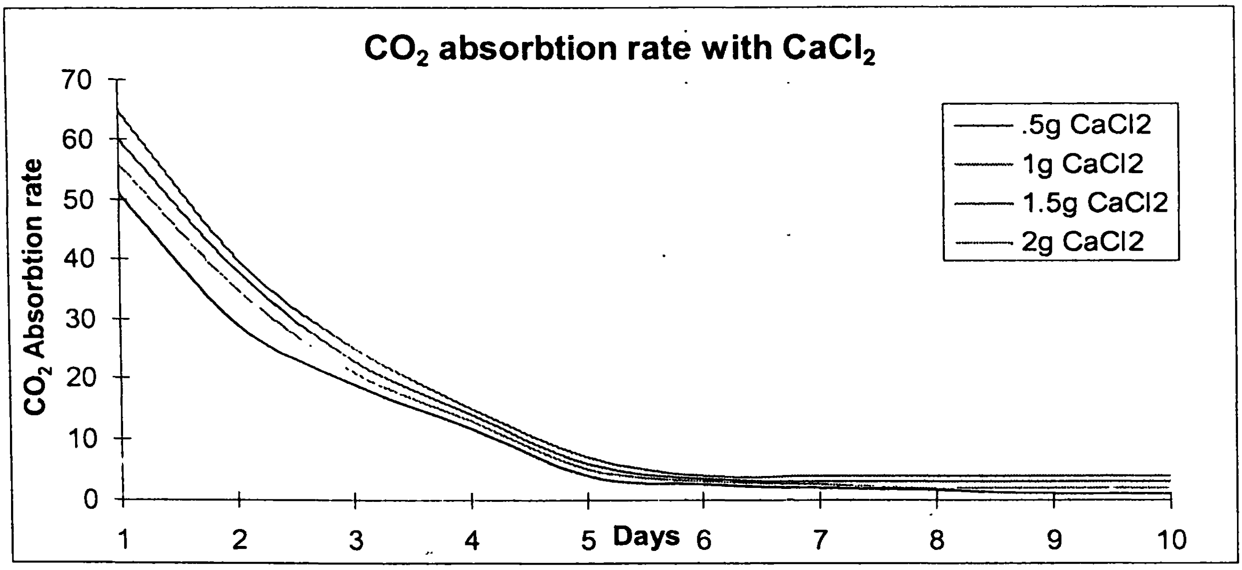
$H_1$: $\mu_1 \neq \mu_2$

P = 0.0012 (adjusted for ties), So $P < 0.05$

Reject $H_0$ at 5% significant difference level

Two samples are not same. Samples without gas absorbent have higher amount of burst packs. So packs with gas absorbent are better. Though pressure gradient affects on package bursting, there were no burst packs with gas absorbent.

Figure 4.2 $CO_2$ absorption rate with $CaCl_2$ (ml / day)




$CO_2$ absorption rate is gradually reduced and becoming to constant rate.

### 4.1.6 Effect of the placing pattern of vertical seal (fin) on package bursting

4.8 No of burst packs with different vertical seal patterns.

| Type | Colombo | | | Gampola | | | Bandarawela | | | Nuwara Eliya | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Left vertical ($\mu_1$) | SP | FP | IP | SP | FP | IP | SP | FP | IP | SP | FP | IP |
| | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | 1 | 3 | 2 | 2 |
| Right vertical ($\mu_2$) | SP | FP | IP | SP | FP | IP | SP | FP | IP | SP | FP | IP |
| | 1 | 0 | 0 | 1 | 0 | 1 | 2 | 1 | 1 | 3 | 2 | 2 |

Above results were analysed using Minitab

$H_0$: $\mu_1 = \mu_2$

$H_1$: $\mu_1 \neq \mu_2$

P = 1.000 (adjusted for ties), So P > 0.05

Reject $H_1$ at 5% significance difference level

Amount of burst packs are same in both sample sets. Bursting pattern of two samples is same.

#### 4.2 Discussion

In upcountry there is high pressure condition is created inside the pack because of low environmental pressure of there.(See Chapter 1.1) If the pack's body is not strong to tolerate that internal force pack will get burst. So SP (strong pack) has high bursting percentage rather than FP (Flexi pack) and IP (flex industries pack). According to the experiment results better samples are FP and IP. According to the gas out places most of the packs were gas out from the vertical seal. To the most of packs vertical seal is the place that easy to burst.

Average environmental temperature of up country is not higher than $28^0$C in Sri Lanka. (See Figure2.4)To this temperature inside gas of the pack does not expand. According to the experiment results environmental temperature does not affect on package bursting.

Vertical sealing temperatures of different packaging materials are mentioned their packing material specifications. Although they were deviated from that there is no difference. According to the experiment results vertical; sealing temperature does not affect on package bursting from the vertical seal.

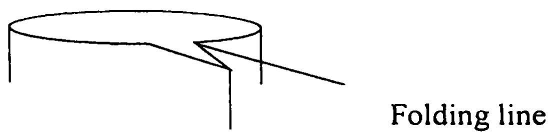
Normally film manufacturer used powder for extrusion lamination to avoid wrinkle and blocking. In specification "This powder application is food grade. It is highest level of fine powder, based on most suitable size of particles for anti-set off /anti blocking. It is made from pure carbohydrates with fine particles not being smaller than 10 microns. It will not scatter and is completely harmless to the human body." were mentioned. So it is fine powder and that will not scatter does not affect on final properties of the packaging material. Also according to the experiment this powder application does not affect on package bursting from vertical seal.

Because of the partial vacuum is formed within the pack (See Chapter 2.9.1) helps to maintain lower internal pressure within the pack according to the lower external pressure. So less bursting percentages are obtained the packs that were flushed from $CO_2$ or $CO_2$ and $N_2$ mixture. So $CO_2$ or $CO_2$ and $N_2$ mixture is better to use as an internal gas according to the experimental results.

According to the Figure 4.1 $CO_2$ absorption rate is higher in Colombo. Other rates are comparatively less with respect to the altitude. Different geographical areas have different environmental conditions. These environmental conditions especially temperature affects on $CO_2$ absorption rate.

Because of the $CaCl_2$. inside $CO_2$ is absorbed furthermore. So vacuum condition is formed within the few days. It helps to maintain equilibrium between environmental pressure and inside environment pressure of the pack. Before formed vacuum condition they have been handled. (Because just after forming packs, are packed into a corrugated box and store in warehouse.) So physical damages do not occur on to the product. According to the experimental results this is successful method. Because at least one pack did not burst. Although inside gas composition was changed there is no difference of the taste and colour within the two month. (But shelf life of the tipi tip is one year, there is not enough time duration to check sensory parameters for the one year)

After observing burst packs most of them were burst along the folding line of the packaging material when forming vertical seal. When forming vertical seal packaging material was folded from one side. (See Figure 4.3)



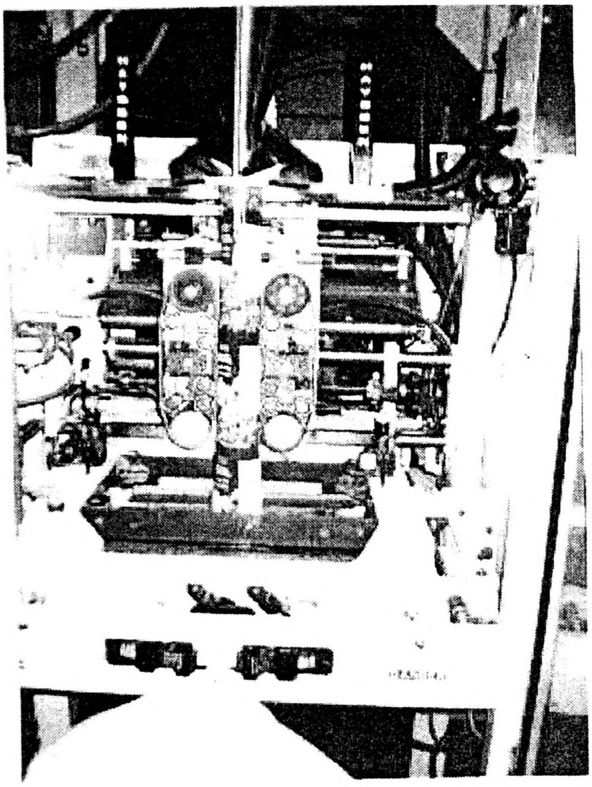
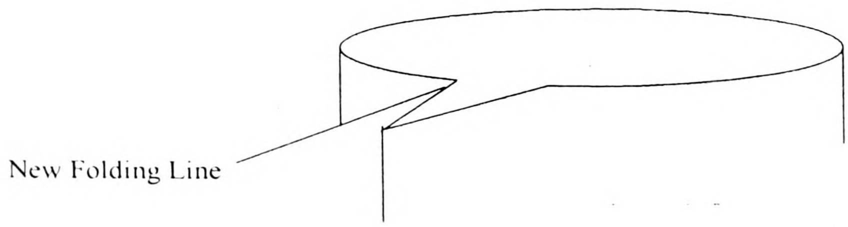


Figure 4.3 Normal way of packs Forming

Aluminum foil and other films were folded. So it may be caused to the package bursting. Also packs that were turned vertical seal to the opposite side after forming were burst along the folding line.



# CHAPTER 5
## Conclusion & Recommendations

### 5.1 Conclusion

Tipi tip is an extruded snack. It is highly sensitive to moisture as its ingress results in softening and loss of crispness. Absorption of moisture causes development of rancidity. It is highly fragile product. Packaging is intended to preserve product from physical damages and extend its shelf life. In the case of elimination of the packs bursting in upcountry following conclusion were gained.

According to the experiments SP was rejected, producing under their normal process flow with nitrogen gas (Because SP had higher bursting percentage). FP and IP were better, producing under their normal process flow with nitrogen gas. But there were packs failure caused by the lower external pressure on the pack in up country.

With carbon dioxide and its absorbent ($CaCl_2$) there was no package bursting of FP, IP and SP too. So cordon dioxide is better to flush than nitrogen or carbon dioxide and nitrogen mixture.

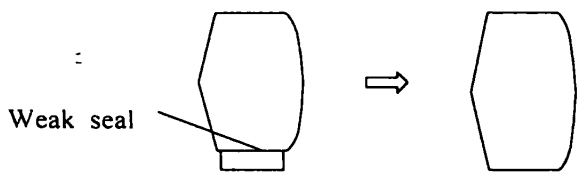
Environmental temperature, vertical sealing temperature and anti wrinkling and anti blocking material did not affect on package bursting. Unless packing material damage, hole puncher damage or cracks on vertical, environmental pressure gradient did not affect on package bursting.

Most of the packs were burst in up country from the vertical seal. It bursts along the packing material folding line of the packing material was found. (When forming vertical seal packaging material was folded from one side.)

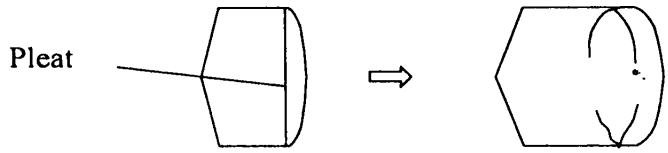
When the package bursting upper PET layer is delaminated and other inside three layers are torn along the folding line.

### 5.2 Recommendations

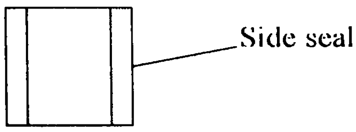
1. Prepare the packs with partially vacuum space devising by weak sealing, which will break in up country increasing inside volume.



2. Prepare the packs with a pleat that would be expanded giving more inside volume to maintain equilibrium pressure in up country.




3. Prepare the packs changing the former of Form-Fill-Seal machine with two side seals instead of one middle vertical seal.




4. Develop the new multilayer film with highly strength inner layer to increase the strength of the packs' body using strong inner layers.
    - LLDPE 40 – 50 micro meter
    - Metallacen 40 – 50 micro meter (Enhanced polyethylene)
5. Manufacture the film to avoid delamination of the upper layer improving manufacturing process. (Extrusion lamination, lamination process or extrusion coating )
6. Changing the layers and thickness of the multilayer film with strong inner layer manufacture the low cost packing material with requirements.

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## APPENDIX 1

## SENSORY EVALUATION SHEET

DATE:

PRODUCT: **TIPI TIP**

- Indicate how many marks you can give for test samples with respect to reference sample after tasting.
- Access the samples individually
- Give numerical values for ranking taste and colour according to the scale
- Rinse your mouth with water after testing each samples

**SCALE**

- 1 Highly poor quality
- 2 Slightly poor quality
- 3 Same quality like reference sample
- 4 Slightly better quality
- 5 Highly better quality

| | TASTE | | COLOUR | |
|---|---|---|---|---|
| | 235 | 852 | 235 | 852 |
| 1. | ...... | ...... | ...... | ...... |
| 2. | ...... | ...... | ...... | ...... |
| 3. | ...... | ...... | ...... | ...... |
| 4. | ...... | ...... | ...... | ...... |
| 5. | ...... | ...... | ...... | ...... |

Specific Comments.

**THANK YOU**

## APPENDIX 2

The SAS System
Analysis of Variance Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| AREAS | 4 | 1 2 3 4 |
| TYPES | 3 | 1 2 3 |

Dependent Variable: BURST

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| AREAS | 3 | 1799.316406 | 599.772135 | 4.82 | 0.0488 |
| TYPES | 2 | 7736.002604 | 3868.001302 | 31.07 | 0.0007 |

T tests (LSD) for variable: BURST
Alpha= 0.05 df= 9 MSE= 282.9319
Critical Value of T= 2.26
Least Significant Difference= 26.906

| T Grouping | Mean | N | TYPES |
|---|---|---|---|
| A | 70.31 | 4 | 1 |
| B | 13.28 | 4 | 2 |
| B | 20.31 | 4 | 3 |

The SAS System
Analysis of Variance Procedure
Class Level Information

| Class | Levels | Values |
|---|---|---|
| DAMAGES | 4 | 1 2 3 4 |

Dependent Variable: BURST

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 5780.508333 | 1926.836111 | 9.06 | 0.0059 |
| Error | 8 | 1701.229133 | 212.653642 | | |
| Corrected Total | 11 | 7481.737467 | | | |

| R-Square | C.V. | Root MSE | BURST Mean |
|---|---|---|---|
| 0.772616 | 58.32282 | 14.58265 | 25.00333 |

T tests (LSD) for variable: BURST
Alpha= 0.05 df= 8 MSE= 212.6536
Critical Value of T= 2.31
Least Significant Difference= 27.457

| T Grouping | Mean | N | DAMAGES |
|---|---|---|---|
| A | 61.82 | 3 | 1 |
| B | 20.64 | 3 | 3 |
| B | 12.37 | 3 | 4 |
| B | 5.19 | 3 | 2 |

# APPENDIX 3

## Friedman Test

Friedman test for C3 by C1 blocked by C2

S = 0.00 DF = 8 P = 1.000

| C1 | N | Est Median | Sum of Ranks |
|---|---|---|---|
| 1 | 3 | 0.00000 | 15.0 |
| 2 | 3 | 0.00000 | 15.0 |
| 3 | 3 | 0.00000 | 15.0 |
| 4 | 3 | 0.00000 | 15.0 |
| 5 | 3 | 0.00000 | 15.0 |
| 6 | 3 | 0.00000 | 15.0 |
| 7 | 3 | 0.00000 | 15.0 |
| 8 | 3 | 0.00000 | 15.0 |
| 9 | 3 | 0.00000 | 15.0 |

Grand median = 0.00000

## APPENDIX 4

The SAS System
Analysis of Variance Procedure

| Class | Levels | Values |
|---|---|---|
| TYPES | 3 | 1 2 3 |
| AREAS | 4 | 1 2 3 4 |
| TEMP | 5 | 1 2 3 4 5 |

Dependent Variable: BURST

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 9 | 3558.333333 | 395.370370 | 11.91 | 0.0001 |
| Error | 50 | 1660.000000 | 33.200000 | | |
| Corrected Total | 59 | 5218.333333 | | | |

| R-Square | C.V. | Root MSE | BURST Mean |
|---|---|---|---|
| 0.681891 | 51.59950 | 5.761944 | 11.16667 |

Dependent Variable: BURST

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| TYPES | 2 | 1463.333333 | 731.666667 | 22.04 | 0.0001 |
| AREAS | 3 | 1885.000000 | 628.333333 | 18.93 | 0.0001 |
| TEMP | 4 | 210.000000 | 52.500000 | 1.58 | 0.1938 |

## APPENDIX 5

**Mann-Whitney Confidence Interval and Test**

With pow N = 4 Median = 1.000
without N = 4 Median = 1.000
Point estimate for ETA1-ETA2 is -0.000
97.0 Percent CI for ETA1-ETA2 is (-2.000,1.000)
W = 16.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.7728
The test is significant at 0.7389 (adjusted for ties)

Cannot reject at alpha = 0.05

## APPENDIX 6

The SAS System
Analysis of Variance Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| AREAS | 4 | 1 2 3 4 |
| TYPES | 3 | 1 2 3 |
| GASES | 3 | 1 2 3 |

Dependent Variable: BURST

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 19412.89137500 | 2773.27019643 | 28.13 | 0.0001 |
| Error | 28 | 2760.56565556 | 98.59163056 | | |
| Corrected Total | 35 | 22173.45703056 | | | |

| R-Square | C.V. | Root MSE | BURST Mean |
|---|---|---|---|
| 0.875501 | 43.23942 | 9.92933183 | 22.96361111 |

| Source | DF | Anova SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| AREAS | 3 | 3999.95556389 | 1333.31852130 | 13.52 | 0.0001 |
| TYPES | 2 | 13751.06790556 | 6875.53395278 | 69.74 | 0.0001 |
| GASES | 2 | 1661.86790556 | 830.93395278 | 8.43 | 0.0014 |

T tests (LSD) for variable: BURST
Alpha= 0.05 df= 28 MSE= 98.59163
Critical Value of T= 2.05
Least Significant Difference= 8.3035

| T Grouping | Mean | N | GASES |
|---|---|---|---|
| A | 32.223 | 12 | 1 |
| B | 20.556 | 12 | 2 |
| B | 16.112 | 12 | 3 |

**Kruskal-Wallis Test (For colour)**
Kruskal-Wallis Test on C2

| C1 | N | Median | Ave Rank | Z |
|---|---|---|---|---|
| 1 | 32 | 3.000 | 31.1 | -0.60 |
| 2 | 32 | 3.000 | 33.9 | 0.60 |
| Overall | 64 | | 32.5 | |

H = 0.36 DF = 1 P = 0.550
H = 0.44 DF = 1 P = 0.509 (adjusted for ties)

**Kruskal-Wallis Test (For taste)**
Kruskal-Wallis Test on C2

| C1 | N | Median | Ave Rank | Z |
|---|---|---|---|---|
| 1 | 32 | 3.000 | 30.2 | -0.99 |
| 2 | 32 | 3.000 | 34.8 | 0.99 |
| Overall | 64 | | 32.5 | |

H = 0.99 DF = 1 P = 0.320
H = 1.10 DF = 1 P = 0.295 (adjusted for ties)

# APPENDIX 7

## Mann-Whitney Confidence Interval and Test

With abs N = 12 Median = 0.000
Without N = 12 Median = 1.000
Point estimate for ETA1-ETA2 is -1.000
95.4 Percent CI for ETA1-ETA2 is (-2.000,0.000)
W = 99.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0039
The test is significant at 0.0012 (adjusted for ties)

## APPENDIX 8

**Mann-Whitney Confidence Interval and Test**

Left ver    N = 12    Median =    2.000
Right ve    N = 12    Median =    2.000
Point estimate for ETA1-ETA2 is    -0.000
95.4 Percent CI for ETA1-ETA2 is (-1.000,1.000)
W = 150.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 1.0000
The test is significant at 1.0000 (adjusted for ties)

Cannot reject at alpha = 0.05