Emerging Technology of Food Preservation in Household Refrigerator

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Abstract - *A vacuum storage system in a refrigerator includes a drawer unit which is removabley mounted in housing. The vacuum storage system may be utilized as a storage space or in a vacuum sealing configuration to remove air from food preservation compartment having one way evacuation valves. A switch on a control interface actuates a vacuum source and a front wall of the drawer unit seals against the box of compartment. Air is drawn from the storage space via a hose in communication with the vacuum source and air pressure within the storage space is reduced below the atmospheric pressure. At a predetermined pressure or time, a control deactivates the vacuum source. Later while opening the drawer a non-return valve is opened to return the storage space to atmospheric pressure.*

Key Words: Vacuum Compartment, Food Freshness, Vacuum cooling, Moisture Loss, Vitamin C.

1. INTRODUCTION

It is well known that exposure to oxygen over time promotes deterioration of food products. Therefore, packaging food in vacuum sealed containers aids in preserving food products and extending their shelf life. Oxygen in air promotes certain reactions in foods that cause deterioration of quality. For example, oxygen can cause fats in food to go rancid as well as cause certain odour and colour changes. Therefore, removal of oxygen from the package environment will preserve certain quality characteristics and extend the food's shelf life. Vacuum packing and sealing is thus a means of food preservation that preserves food for a long period of time than conventional plastic wrap or storage bags. Vacuum sealers are commonly used to extend the storage time of refrigerated, dried and frozen foods.

Fresh items such as fruit and vegetables are respiring, transpiring, senescing and dying all at the same time. It is generally accepted that the quality of fruits and vegetables begins to deteriorate upon harvesting and continues to decline quickly thereafter. The effect of temperature on shelf life and decay is dramatic. Vacuum cooling can rapidly and conveniently reduce temperature due to field heat. Vacuum cooling is the standard commercial procedure used for lettuce in many European countries, as well as in the US.

1.1 Objectives

The objectives of present work are to develop,

- The compartment to provide a vacuum food storage system in a refrigerator
- The vacuum compartment is intended for food that spoils easily, such as raw meat, fruits, vegetables, etc. and it is sealed with a special door.
- After closing, a pump is activated automatically with the press of a button to remove air from the sealed drawer and reduce the air pressure to 0.8 bars.
- The system should keep food fresh longer than non-vacuum cooled food. It also eliminates the need for defrosting.

1.2 Necessity of the device

- Increases life of food by removing oxygen.
- This reduces growth of spoilage bacteria.
- Reduces ice crystals on frozen food.
- Enhances the shelf life of the food products.
- Reduces the smell & odor of the meat food products.

2. METHODOLOGY

- Recognising the necessity of the device.
- Literature review regarding concerned topic.
- Study of existing different means of vacuum creations & food preservation.
- Development of various concepts to create vacuum.
- CAD modelling of the selected concepts.
- Failure Effect Mode Analysis (FMEA) of the concepts.
- Modifying the selected concepts according to FMEA.
- Finite Element Analysis of the selected concept.
- Development of the prototypes.
- Experimental testing of the developed prototypes

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3. SYSTEM DESCRIPTION

The present project is directed to a refrigerator vacuum storage system and method of use. The vacuum storage system includes a compartment, such as a drawer unit, which is mounted in the cabinet to define a removable storage space for food products. An optional shelf having air flow apertures therein may be utilized to divide the storage space into separate storage compartments. The drawer unit can be used to store food in a conventional manner, or may be utilized to remove air from compartment to enhance food preservation within the compartment. To this end, a vacuum source in a machine compartment of the refrigerator is placed in communication with the storage space. The desired, compartment to be evacuated is placed into the refrigeration compartment and the vacuum source is actuated via a switch provided on the cabinet. Air pressure within the storage space is reduced, thereby evacuating air within the compartment.

After a predetermined pressure is attained, or after a particular predetermined time, the vacuum source is shut off. During opening of compartment an equalizing valve is opened which returns the storage space to atmospheric pressure, while vacuum conditions are retained in the compartment.

With this system, a consumer is provided with a food storage drawer that may be shifted between an extended or opened position and a retracted or closed position with ease, but which also may be utilized to simultaneously evacuate air from compartment, depending on a consumer's needs.

3.1 Selection of vacuum pump

So, our task is to find out the suitable pump having desired pumping speed range.
We have a known volume and maximum time to be taken to evacuate the vacuum chamber of known volume.
The question arise here is how will we know the pumping speed for a known volume?

The formula for finding out the pumping speed of a pump to evacuate a chamber of known volume within a particular time is given by;

$$\frac{-dP}{dt} = \frac{S}{V} * P$$

$$=> \int_{Patm}^{P} \frac{dP}{dt} = -\frac{S}{V}\int_{0}^{t} dt$$

$$=> ln\left(\frac{P}{Patm}\right) = -\frac{S}{V} * t$$

$$=> S = \frac{V}{t} ln\left(\frac{P}{Patm}\right)$$

Where,
S= pumping speed (litres/sec)
P_{atm}= Atmospheric pressure (mbar), 1013 mbar
P = desired pressure or ultimate pressure (mbar)
V = Volume of the chamber, (litres).
t = time taken to evacuate volume of 'V' from pressure P_{atm} to P.

3.2 Selection Criteria for vacuum pump

- Pumping speed
- Operating pressure
- Process conditions
- Standards and regulations which depend on the area of application and the produced products.

For creation of the vacuum in this unit, an electrical vacuum pump of small size was used. The 12 V micro diaphragm vacuum pump is mounted on the compressor mount plate near the compressor of the refrigerator. The different concepts for the vacuum compartment were therefore built as per the requirement. The micro diaphragm vacuum pump was connected to the vacuum compartment with the pipe of diameter 8 mm. The aim of using the pump was to create the vacuum of 0.8 bars
The details of vacuum pump are as follows.
Rated Voltage: 12V
Rated Current: 1800mA
Flow Rate: 13.0 lpm
Output pipe diameter: 7mm
Size: ϕ 60mm × 120mm
Negative Pressure: -375mmHg (-50KPa)
Maximum Pressure: 525mmHg (70KPa)

4. CAD Modelling of Vacuum Compartment

Two concepts were developed for designing of vacuum compartment. One concept was box and drawer assembly, while other was box and lid assembly.

4.1 Concept 1

The present unit is directed to a refrigerator vacuum storage system and method of use. The vacuum storage system includes a cabinet and a bin, such as a drawer unit, which is mounted in the cabinet to define a removable storage space for food products.
The bin or drawer unit can be used to store food in a conventional manner. To this end, a vacuum source mounted on the CMP of the refrigerator is placed in connection with the storage space by the means of pipe. When desired compartment is to be evacuated are placed into the storage space and the vacuum source is actuated via a control interface on the cabinet. Air pressure within the storage space is reduced to 0.8 bars thereby evacuating air from the

compartment. After a predetermined pressure is attained the vacuum source is shut off.

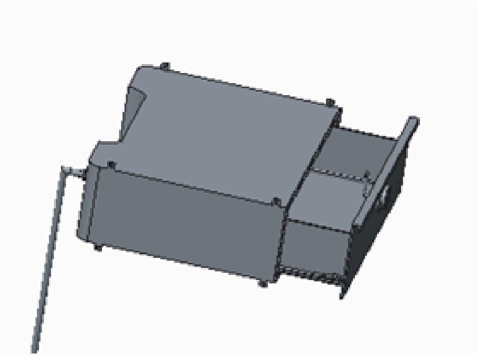

Fig -1: CAD Modelling of Concept 1

4.1 Concept 2

This concept consists of the hinged door with a typical locking mechanism to avoid the leakages in order to maintain the desired mechanism. The vacuum compartment is connected to the vacuum source by the means of vacuum hose as like in the previous concept. The vacuum source is mounted on the compressor mount plate near to the compressor. The switch is provided at the front end near the locking mechanism, so that after the closure of the door, the vacuum pump is started for the desired time to evacuate the air from the compartment.

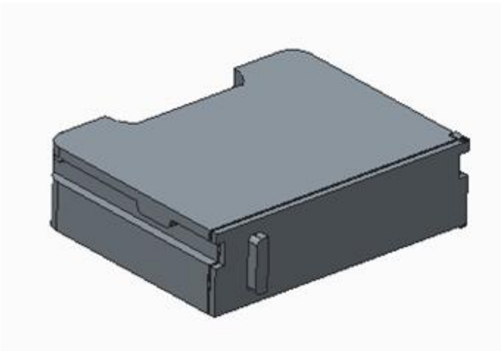

Fig -2: CAD Modelling of Concept 2

5. PROTOTYPE DEVELOPMENT

The material used was High Impact Polystyrene (HIPS) and General Purpose Polystyrene (GPPS). Chloroform $CHCl_3$ in mixture with fine HIPS powder was used as a sealing agent to avoid the vacuum losses.
Prototypes developed were 1:1 scaled model of actual product. Properties of material are as follows

Table -1: Properties of Material

Material	Modulus of Elasticity (MPa)	Poisson's Ratio	Yield Strength (MPa)	Tangent Modulus (MPa)
HIPS Class 7	1780	0.36	23	178
GPPS	2640	0.35	38	0.35

Fig -3: Prototype development of Concept 1

Fig -4: Prototype development of Concept 2

a)

b)

Fig -5: Placement of vacuum compartment in refrigerator for a) Concept 1 b)Concept 2

6. EXPERIMENTAL VALIDATION

Two similar refrigerators with same performance criteria were used for experimentation. One refrigerator was equipped with vacuum compartment and the other was not equipped with vacuum compartment.

Food freshness test was to be taken on vegetables like spinach, coriander and carrot for 7 days.

Both the products were allowed to stabilize and obtain same temperature. These products were then loaded by vegetables. The moisture loss was then estimated by measuring the weight every 24 hours.

6.1 Moisture Loss in Spinach

Moisture loss was determined by weighing the samples before test and after the test. The loss in weight indicates moisture loss. The test was carried out for 7 days with standard door opening procedure. The results of this test are as shown below.

Table -2: Moisture loss in Spinach

Days	Moisture loss of Spinach in gram	
	With vacuum	Without vacuum
Day-0	130	130
Day-1	126.2	124.5
Day-2	125.3	118.3
Day-3	125	111.2
Day-4	122.8	105.4
Day-5	121.5	99.5
Day-6	118.7	93
Day-7	116	88.9

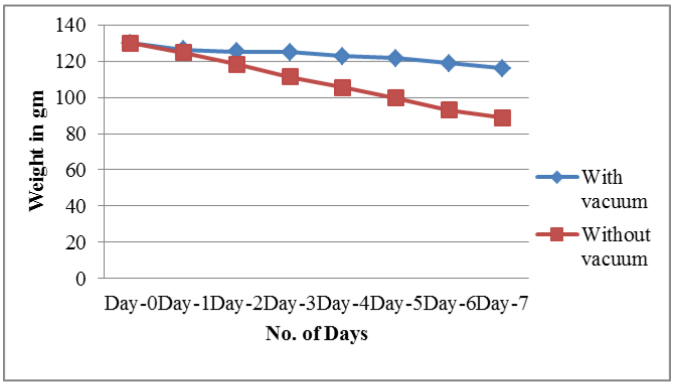

Chart -1: Graph indicating the difference of moisture loss in coriander with vacuum compartment and without vacuum compartment.

6.2 Moisture Loss in Carrot

The results of this test are as shown below.

Table -3: Moisture loss in Carrot

Days	Moisture loss of Carrot in gram	
	With vacuum	Without vacuum
Day-0	387.5	353
Day-1	383	347
Day-2	382.5	343.5
Day-3	382	339
Day-4	380.5	335.5
Day-5	378	332
Day-6	376.5	329
Day-7	375.5	324

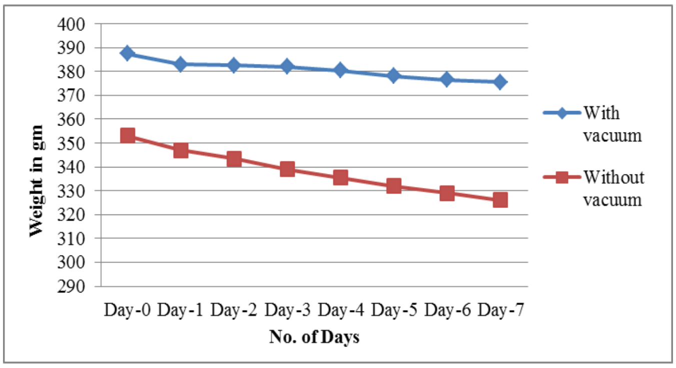

Chart -2: Graph indicating the difference of moisture loss in carrot with vacuum compartment and without vacuum compartment

6.2 Moisture Loss in Coriander

The results of this test are as shown below.

Table -4: Moisture loss in Coriander

Days	Moisture loss of Coriander in gram	
	With vacuum	Without vacuum
Day-0	84.5	102
Day-1	83	98
Day-2	81	94
Day-3	79.5	92
Day-4	78	89.5
Day-5	76.5	86
Day-6	75	83.5
Day-7	73	80

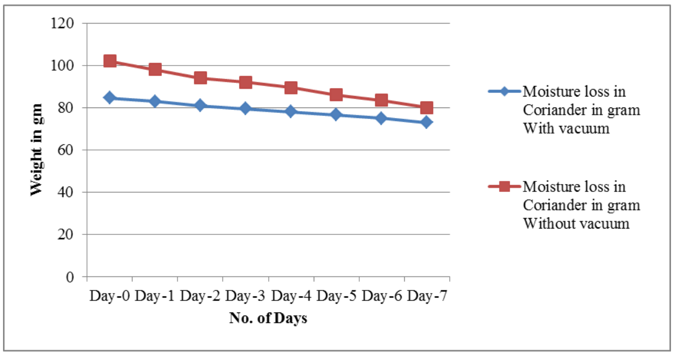

Chart -3: Graph indicating the difference of moisture loss in carrot with vacuum compartment and without vacuum compartment

6.4 Determination of Vitamin C in Spinach

As Spinach is the rich source of Vitamin C, it was selected for vitamin C determination.

Test Procedure:

1. 10gm of sample of Spinach + 90 ml 3% Metaphosphoric acid
2. Mix the sample and Metaphosphoric acid in a beaker with a mixer.
3. Filter the mixture with the help of filter paper.
4 Fill the burette with Dye Solution.
5. Add the dye solution to sample in the beaker until the solution turns from colourless to the pink colour.

$$\text{Dye Factor} = \frac{0.5}{Titre} = \frac{0.5}{4.5} = 0.1111$$

mg of ascorbic acid per 100 g or ml =

$$\frac{(Titre) * (dye\ factor) * (volume\ made\ up) * (100)}{(a\ liquot\ of\ extraction\ taken\ for\ estimation) * (Weight\ or\ volume\ of\ sample\ taken\ for\ estimation)}$$

$$= \frac{2.7 * 0.1111 * 100 * 100}{10 * 10}$$

= 29.9997 ≈ 30 mg

The results of this test are as follows

Table -4: Vitamin C loss in Spinach

Day	Vitamin C in mg	
	With Vacuum	Without Vacuum
Day 0	30	30
Day 3	24.38	20.65
Day 5	18	15.23
Day 7	12.825	9.15

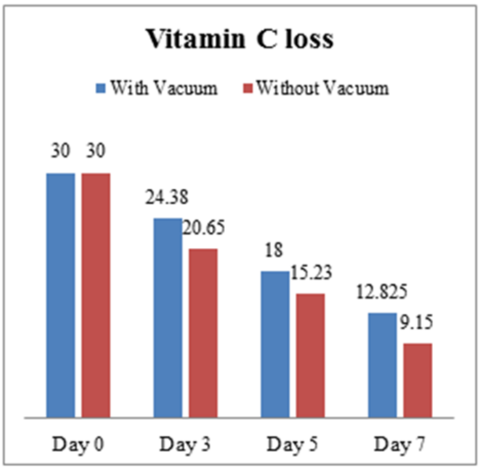

Chart -4: Graph indicating the loss in Vitamin C in Spinach with vacuum compartment and without vacuum compartment

7. OBSERVATION FROM VEGETABLE FRESHNESS TEST

Following observations were found from vegetable freshness test which was conducted for 7 days.

Table -5: Observations from food freshness test

Sample	Weight loss in g/100g	
	With Vacuum	Without Vacuum
Spinach	10.8	31.6
Carrot	8.9	10
Coriander	13.6	21.56

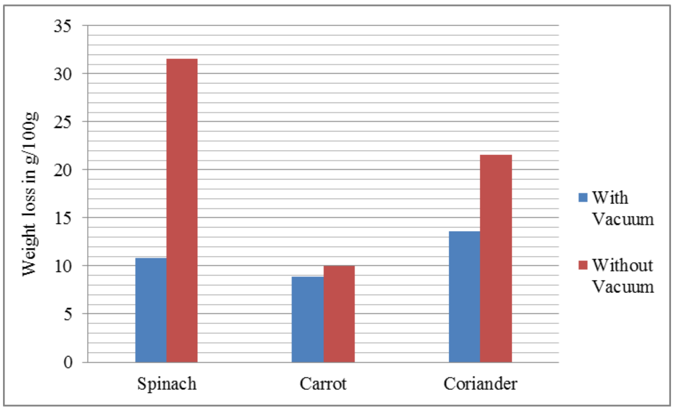

Chart -5: Graph indicating the difference of vegetable preservation (weight loss in g/100g) with vacuum compartment and without vacuum compartment

8. CONCLUSIONS

1) The loss in weight in the sample provided from the refrigerator with vacuum compartment is less as compared to that of the sample provided from refrigerator without vacuum compartment.
2) The loss in vitamin C in the sample provided from the refrigerator with vacuum compartment is less as compared to that of the sample provided from refrigerator without vacuum compartment
3) Also the nutrient values were found to be preserved in the vacuum storage for longer time than non-vacuum storage.

Hence it can be stated that, vacuum compartment in refrigerator increases the food life than conventional refrigerator storage.

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