Int.J.Curr.Microbiol.App.Sci (2017) *6*(12): 119-128

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 12 (2017) pp. 119-128**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.612.016

Textural and Sensory Characteristics of Freeze Dried Tofu

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Keywords

Soybean, Tofu, Freeze drying, Rehydration characteristics, Textural characteristics.

Article Info

Accepted:
04 October 2017
Available Online:
10 December 2017

A B S T R A C T

Tofu (Soypaneer) is a nutritional product prepared from soybean (*Glycine max*), has very low shelf life. Drying is the most widespread method which not only reduces weight and volume of the product thereby, minimizes transportation cost but also increases shelf life. Freeze drying is a process by which a solvent is removed from a frozen material by sublimation under reduced pressure. In the present investigation tofu was freeze dried at -40 °C. Textural (hardness, cohesiveness, springiness, and chewiness), rehydration, sensory and some physical characteristics (colour, water activity) of tofu have been analysed. The colour and water activity and textural properties computed/measured using hunter lab colourimeter, Hygrolab-3 and texture analyzer, respectively. Rehydration characteristics were calculated as described by Ranganna (2000). The sensory evaluation was performed on 9 point hedonic scale based on ISI (1971). The values of the rehydrated freeze dried tofu samples were recorded as colour (57.71), water activity (0.971), rehydration characteristics [rehydration ratio (2.28), coefficient of rehydration (0.99) and percent of water in rehydration (75.79)], textural properties [hardness (1367.862), cohesiveness (0.964), adhesiveness (12.227), springiness (0.11) and chewiness (144.636)] and sensory evaluation [colour (8.0), taste (7.50), appearance (7.45) and over all acceptability score (7.65)]. The qualities of rehydrated freeze dried tofu were found closer to fresh tofu.

Introduction

Soybean (Glycine max) is one of the nature's wonderful nutritional gifts. It is considered as "Gold" obtained from soil and is thus rightly called today the “Gold Nugget of Nutrition” owing to its nutritional composition and native to East Asia (Singh *et al.*, 2001). Use of soybeans for the manufacture of nutritious products such as tofu, soy cheese and fermented soy products for human consumption has been known from a long time in the Far East. Tofu though highly nutritious, has low shelf life. Many researchers have presented various preservation techniques and check qualities.

Drying is the most widespread method which reduces weight and volume of the product thereby, minimizes transportation cost and increase in shelf life. Among the various types of dryer Freeze drying is a process by which a solvent is removed from a frozen material by sublimation of the solvent and by desorption of the sorbed solvent, generally under reduced pressure (Boss *et al.*, 2004). Freeze drying cycle can be divided into three steps: freezing solidification, primary drying (ice sublimation) and secondary drying (desorption of unfrozen water) (Abdelwahed *et al.*, 2006). It provides dried products of

porous structure and little or no shrinkage, superior taste retention, better rehydration properties, compared to products of alternative drying processes (Karthanos *et al.*, 1996) Quality is one of the important parameter in processing to ensure quality of finished products. Control should be exercised at every stage from pre-processing to packaging, storage etc. Texture is regarded as a manifestation of rheological properties of food. The texture of food is one of the most challenging areas of food characteristics and main quality parameter affecting food preference. Texture of food is defined as the response of the tactile senses to physical stimuli that result from contact between some part of the body and food (Bourne, 1978). Qualities of rehydrated tofu were evaluated on the basis of several parameters viz. colour, water activity, rehydration characteristic and textural characteristic and sensory evaluation. The development of instrumental methodologies such as Texture Profile Analysis (TPA) has increased the interest in qualifying textures.

Freeze drying also termed as ‘‘lyophilisation’’ is a successful process of liquid separation from a product in a frozen state, achieved by sublimation under vacuum. Sublimation serves to obtain a product that retains even its volatile components and initial quality and the vacuum is used to maintain the physical state as frozen and to direct the vapor flow. In this drying process water is directly converted from solid state (ice) to the vapor state without passing through the liquid state. Sublimation of water can take place at pressures and temperature below triple point i.e. 4.579 mm of Hg and 0.0099 degree Celsius (Fellows, 1988).

Materials and Methods

This includes the description of experimental set up and methodology used in drying of tofu by freeze dryer and conducted to assess the quality of dried and rehydrated dried products. The experiment conducted in department of processing and food engineering, CTAE College, Udaipur, Rajasthan. The fresh Soybean was used in these investigations which were procured in bulk from local market of Udaipur in the state of Rajasthan (India).

Sample preparation

A sample of about 500 g cleaned soybean was soaked in cold water for 4-6 h then removal of outer layer from the soybean by manually and ground in domestic mixer grinder in hot water. The ground slurry was boiled and filtered through muslin cloth. The water extract of soybean henceforth called as soymilk was filtered with double layered muslin cloth and heated to 80 °C and then coagulated with citric acid 0.2 per cent. The curd was gently transferred and pressed in paneer press for about 15 min after the whey is removed. The tofu block thus obtained was immediately kept in chilled water (Verma and Jain, 2002). Process flow chart for preparation of tofu is presented in Figure 1. The 2×2×1 cm size tofu samples weighing 250 g were loaded in freeze dryer at -40^0 C for drying until completion of experiment (up to EMC).

The samples were used to determine the quality on the basis of several parameters viz. colour, water activity, rehydration characteristics and textural characteristics.

The initial moisture content of fresh tofu samples before drying was determined suggested by Ranganna (2000) as:

$$\text{Percent moisture content (wb)} = \frac{W_1 - W_2}{W_1} \times 100 \qquad (1)$$

Where, W_1 is mass of original sample and W_2 is mass of the sample after drying in oven at 105 °C for 24 hours.

Quality evaluation

Colour

Colour is important to consumer for judging (identification) quality. There are several colour scales used in a Hunter Lab Colourimeter such as *L**, *a** and *b** in which *L** is the lightness coefficient, ranging from 0 (black) to 100 (white), *a** is purple-red (positive *a** value) and blue-green (negative*a** value) and *b**, that represents yellow (positive *b** value) or blue (negative *b** value) colour (McGuire, 1992).

Water activity

Water activity is a function of moisture content in the food and the temperature (Ratti and Mujumdar, 2001). Most bacteria do not grow at water activities below 0.91 and most molds cease to grow at water activities below 0.80 (Leung, 1986). A digital water activity meter (hygrolab-3) was used in measuring water activity of the samples.

Rehydration characteristics

Rehydration is a complex phenomenon affected by numerous factors. Important factor that would affect the rehydration is the changing of cell structure during the drying process due to drying product temperature. Most dried food need to be rehydrated by soaking in water prior to consumption. There are several factors affecting rehydration, such as the soaking period, temperature of the water, and the rehydration capacity of the product. Rehydration study was carried out by dipping approximately 100 g of dried sample in 400 ml distilled water and maintain at 30-50 °C temperature for 10-30 min. After rehydration, sample was taken out from distilled water and surface moisture was absorbed carefully with tissue paper and then weighed. The rehydration ratio was calculated as of Ranganna (2000).

Rehydration ratio

$$\text{Rehydrationratio} = \frac{W_r}{W_d} \quad (2)$$

Coefficient of rehydration

$$\text{Coefficientofrehydration} = \frac{W_r \times (100 - \text{m.c.beforedrying})}{(W_d - \text{m.c.ofdryproduct}) \times 100} \quad (3)$$

Per cent of water in rehydration

$$\text{Percentofwaterinrehydration} = \frac{W_r - (W_d - \text{m.c.ofdryproduct})}{W_r} \times 100 \quad (4)$$

Where,

W_r = Weight after rehydration of tofu, g
W_d = Weight before rehydration of tofu, g

Texture profile analysis (TPA)

The texture analyzer is a microprocessor controlled texture analysis system, which can be interfaced to a wide range of peripherals, including PC-type computers that recorded the data via a software program XT.RA Dimension, version 3.7H (Texture Technologies Corp., Scardale, Ny.) (Bourne, 1988). It measures force, distance, and time in a most basic test, thus providing three dimensional product analysis. The probe carrier contains a very sensitive load cell. The TA.HD plus load cell has electronic overload protection. Experiments were carried out by TPA test of instrumental texture measurement. The sample is deformed and the extent of the deformation and/or the resistance offered by the sample is noted and used as an index of the texture of the food. During the testing, the samples were held manually against the base plate. The test consists of a 75 mm diameter stainless steel cylindrical probe compressing a bite-size piece of food two times in a reciprocating motion at speed 1 mm/s that imitates the action of the jaw and extracting from the

resulting force-time curve a number of textural parameters that correlate well with sensory evaluation of those parameters. The typical textural profile (force-deformation) curve obtained with one complete run is presented.

Textural properties

The textural properties of rehydrated tofu at room temperature were computed by using Texture Analyzer Stable Micro Systems on stated above and as per the method suggested by Jain and Mhatre (2009).

Hardness

Hardness is defined as the maximum peak force during the first compression cycle (first bite) and has often been substituted by the term firmness.

Cohesiveness

Cohesiveness is defined as the ratio of the positive force area during the second compression to that during the first compression. Cohesiveness may be measured as the rate at which the material disintegrates under mechanical action.

Adhesiveness

Adhesiveness is defined as the negative force area for the first bite and represents the work required to overcome the attractive forces between the surface of a food and the surface of other materials with which the food comes into contact.

Springiness

Springiness (originally called elasticity) is related to the height that the food recovers during the time that elapses between the end of the first bite and the start of the second bite.

Chewiness

Chewiness is defined as the product of gumminess x springiness (which equals hardness x cohesiveness x springiness) and is therefore influenced by the change of any one of these parameters.

The following settings were used for the texture analysis

Parameters

Pre-test Speed: 1.00 mm/s; Test Speed: 5.00 mm/s; Post Test Speed: 5.00 mm/s; Distance: 30 mm; Stop plot: Start position

Trigger

Trigger Type: Auto (Force); Trigger Force: 30.00 g

Probe

Probe type: Compression plate probe (NS P/75)

Sensory evaluation

Sensory analysis provides marketers with an understanding of product quality, directions for product quality and profiles of competing products and evaluations of product reformulations from a consumer perspective.

The prepared products pieces were evaluated for its sensory characteristics such as colour, taste, appearance and overall acceptability and compared with sensory characteristics of rehydrated product.

The sensory evaluation was performed with the help of 20panelists on the basis of numerical sensory card based on (ISI, 1971a). The average scores of all the panelists were computed.

Results and Discussion

Characteristics of fresh tofu

The average values of moisture content, water activity and colour value are presented in Table 2. The moisture content value of fresh tofu samples varied from 75.37 to 76.64 per cent with average value of 76 % (wb) or 316.67 % (db). The colour value (L* value) was recorded as 79.63. The water activity was recorded as about 0.98.

Tofu weighing 500 g was obtained by 200 g of soybean as per the procedure. The tofu was sliced in 2×2×1 cm size of sample and 250 g samples of tofu sample were used for all dehydration experimental trials.

The textural profile (Force-Time curve) for the fresh tofu using a compression plate probe is illustrated graphically in Figure 2 and values of these shown in Table 3. There values have been used to compare with the textural properties of rehydrated tofu.

Quality analysis of rehydrated freeze dried tofu

The rehydrated freeze dried tofu samples were further evaluated for their quality aspects such as colour, water activity, rehydration characteristics, textural properties and sensory evaluation and discussed in this section. The dehydrated and rehydrated freeze dried tofu is shown in Plate 1.

Colour

Colour is often used as an indication of quality and freshness for food products. Hence it has become important for food processors to be able to evaluate and grade their products based on colour. Colour values measured using a hunter lab colourimeter, were relative to the absolute values of perfect reflecting diffuser as measured under the same geometric conditions (ASTM method). Observations were taken at room temperature 30.5 °C and 25 per cent relative humidity. L* value represents lightness index of the product, the chromaticity coordinate a* measures red when positive and green when negative and the chromaticity coordinate b* measures yellow when positive and blue when negative. It was observed that, the L* value of rehydrated freeze dried tofu samples was found to vary from 57.65 to 57.77 with the mean L* value of 57.71. Also a* and b* value was found about 5.64 and 22.94 (Table 4).

Water activity

Water activity was determined using a Hygrolab-3 water activity meter, at a temperature of 16 °C for sample. The value of water activity of dehydrated and rehydrated freeze dried tofu at -40 °C drying temperature was found 0.413 and 0.971 respectively.

Rehydration characteristics

In this study the value of the rehydration ratio, coefficient of rehydration and per cent of water in rehydration of freeze dried sample was 2.28, 0.99 and 75.79 at -40 °C drying temperature respectively. These calculated values are shown in Table 5. The rehydration ratio of freeze dried sample was about 2.28 depending on the experimental condition.

Textural characteristics

The textural profile (Force-Time curve) for the rehydrated tofu dried at -40 °C temperature in freeze dryer, using a compression plate probe is illustrated in Figure 3 and the analysed parameter of textural properties such as hardness, cohesiveness, adhesiveness, springiness and chewiness from these curves have been presented in Table 6.

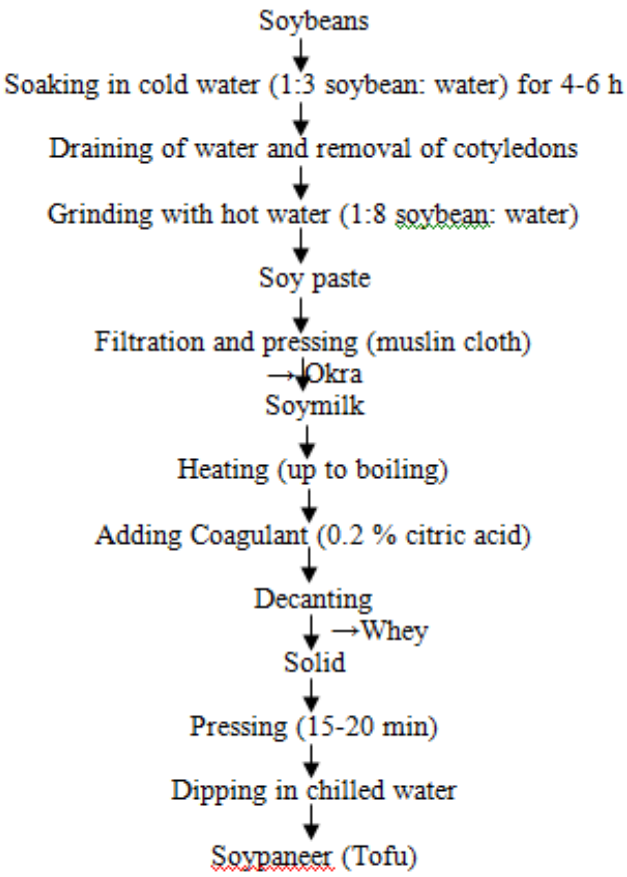

Fig. 1: Process flow chart for the preparation of tofu

Fig.2 Textural profile (Force-Time curve) for the fresh tofu

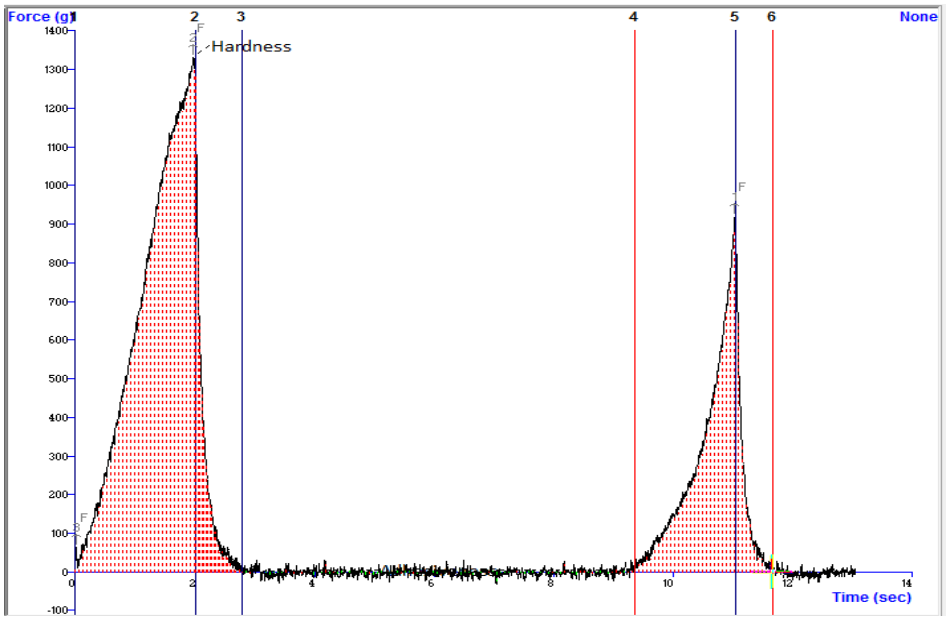

Fig.3 Textural profile (Force-Time curve) for rehydrated tofu dried at -40 °C

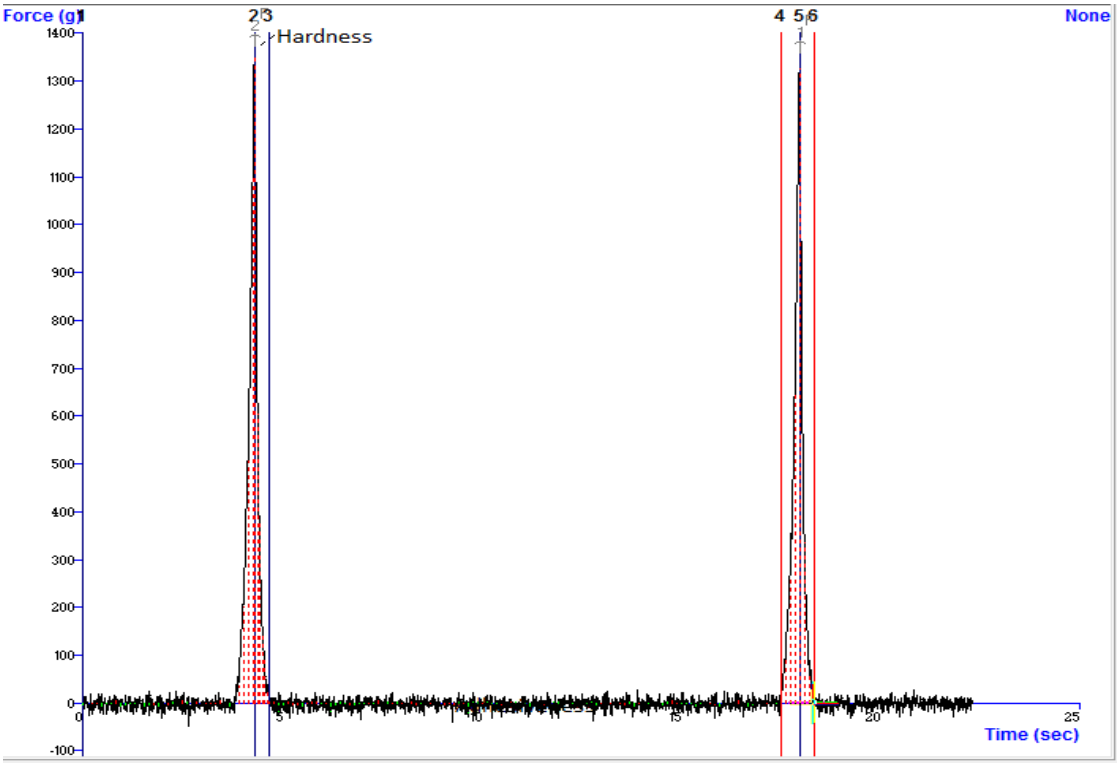

Fig.4 Mean sensory score of rehydrated freeze dried tofu

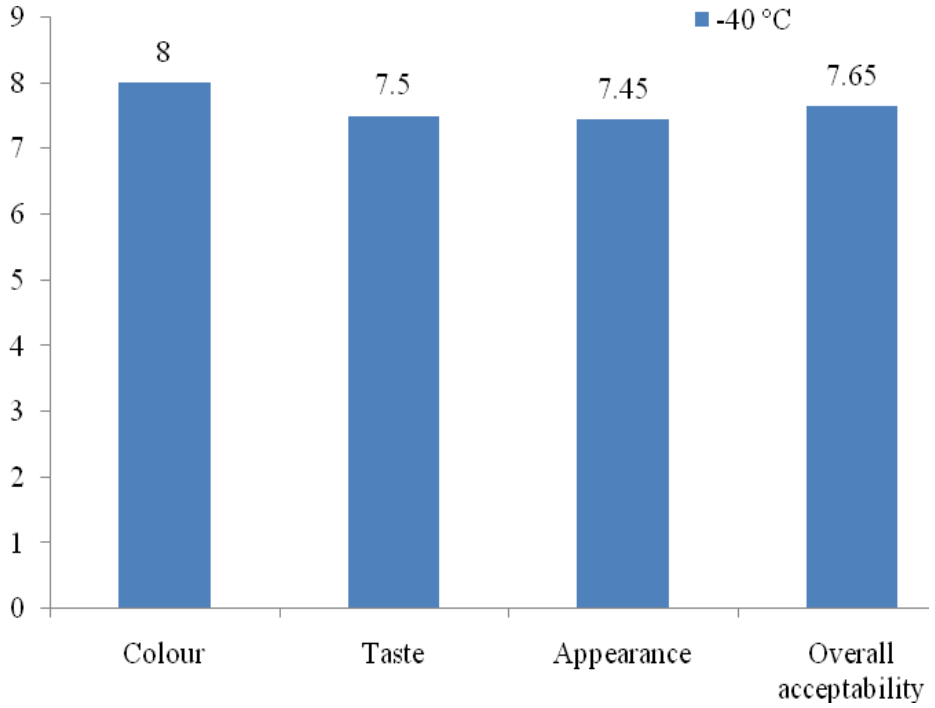

Plate.1 Dehydrated and rehydrated tofu dried at -40 °C temperature in freeze dryer

Table.1 Score cards for sensory evaluation

Quality grade description	Score
Liked extremely	9
Liked very much	8
Liked moderately	7
Liked slightly	6
Neither Liked nor- disliked	5
Disliked slightly	4
Disliked moderately	3
Disliked very much	2
Disliked extremely	1

Table.2 Quality parameters of prepared fresh tofu

Characteristics	**Mean**
Moisture content (wb), %	76.00±0.0064
Colour value (L* value)	79.63±0.05
Water activity	0.98±0.0015

Table.3 Value of textural properties of prepared fresh tofu

Hardness, g	**Cohesiveness**	**Adhesiveness, g.s**	**Springiness**	**Chewiness**
1334.443	0.397	-2.449	0.837	443.167

Table.4 Lightness (L* values) rehydrated tray dried tofu

Drying temperature, **°C**	**L* value**	**a***	**b***
-40	57.71	5.64	22.94

Table.5 Reconstitution characteristics of freeze dried tofu

Drying temperature, °C	Rehydration ratio (RR)	Coefficient of rehydration (COR)	Per cent of water in rehydration
- 40	2.28	0.99	75.79

Table.6 Textural characteristics of rehydrated tray dried tofu

Drying temperature, °C	Hardness, g	Cohesiveness	Adhesiveness, g. s	Springiness	Chewiness
-40	1367.862	0.964	-12.227	0.11	144.636

The hardness, cohesiveness, adhesiveness, springiness and chewiness value of rehydrated tofu samples dried in freeze dryer at -40 °C temperature were obtained 1367.862, 0.964, -12.227, 0.11 and 144.636 respectively which were found to be reached near to the value of fresh tofu (Table 2).

Sensory evaluation

Sensory evaluation was conducted for colour, taste, appearance and overall acceptability. The score ranged from 1 to 9 which represented from "Like extremely" to "Dislike extremely" (Table 1).

The rehydrated samples were tested by a panel of 20 judges. The mean sensory score of rehydrated freeze dried tofu samples are shown in Figure 4.

The values of the colour, taste, appearance and over all acceptability score of rehydrated freeze dried tofu was found 8.0, 7.50, 7.45 and 7.65 at -40 °C drying temperature respectively. It can then be informed from Figure 4 that the rehydrated tofu dried at -40 °C was accepted by consumer panel and rated as liked very much.

The rehydrated freeze dried tofu samples were recorded good values and the pannal accepted to maintain good quality freeze dried tofu sample.

Acknowledgment

The authors are grateful to The College of Technology and Engineering, Udaipur, India for providing financial assistance and the facilities to execute this research project.

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How to cite this article:

Chavan, S.M., R.C. Verma and Raviteja. 2017. Textural and Sensory Characteristics of Freeze Dried Tofu. *Int.J.Curr.Microbiol.App.Sci.* 6(12): 119-128.
doi: https://doi.org/10.20546/ijcmas.2017.612.016