SCREENING OF SELECTED RICE VARIETIES FOR PUFFING

BY

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B.Sc (Hons.) Home Science

THESIS SUBMITTED TO THE PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

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(FOODS AND NUTRITION)

2017

DECLARATION

I, **HAJERAH KHAN**, hereby declare that the thesis entitled "**SCREENING OF SELECTED RICE VARIETIES FOR PUFFING**" submitted to **Professor Jayashankar Telangana State Agricultural University** for the degree of **Master of Science in Home Science** is the result of the original research done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: **Hyderabad** **(HAJERAH KHAN)**

I.D. No. HHM/2014- 006

Date:

CERTIFICATE

Ms **HAJERAH KHAN** has satisfactorily prosecuted the course of research and the thesis entitled "**SCREENING OF SELECTED RICE VARIETIES FOR PUFFING**" submitted is the result of the original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any university.

Place: Hyderabad

Date:

Chairperson

(DR. S. SUCHIRITHA DEVI)

CERTIFICATE

This is to certify that the thesis entitled "**SCREENING OF SELECTED RICE VARIETIES FOR PUFFING**" submitted in partial fulfilment of the requirements of the degree of **MASTER OF SCIENCE IN HOME SCIENCE** of the Professor Jayashankar Telangana State Agricultural University, Hyderabad, is a record of the bonafide original research work carried out by **Miss. HAJERAH KHAN** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all the assistance received during the course of investigation have been duly acknowledged by the author of the thesis.

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HAJERAH KHAN

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mm	:	Millimeter
cm	:	Centimeter
m	:	Meter
km	:	Kilometer
mg	:	Milligram
g	:	Gram
kg	:	Kilogram
ml	:	Millilitre
t	:	Tonne
ha	:	Hectare
ac	:	Acre
cm^3	:	Centimeter cube
Kg ha^{-1}	:	Kilogram per hectare
N	:	Newton
%	:	Percent
^oC	:	Degree Celsius
^oF	:	Degree Fahrenheit
HTST	:	High Temperature Short Time
et al.	:	and others people
etc.	:	and so on; and other people/things
e.g.	:	for example, for instance
P	:	Processed
U	:	Unprocessed
No.	:	Number
Sec	:	Second
min	:	Minute
h	:	Hour

Kcal	:	Kilo Calories
wt	:	Weight
ht	:	Height
r^2	:	Radius square
Rpm	:	Rotations per minute
Fig.	:	Figure
AOAC	:	Association of Official Analytical Chemist
FAO	:	Food and Agriculture Organization
RS	:	Resistant starch
IVCHO	:	In vitro carbohydrate digestibility
IVPD	:	In vitro Protein digestibility
Hcl	:	Hydrochloric acid
KOH	:	Potassium Hydroxide
NaOH	:	Sodium Hydroxide

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ABSTRACT

Rice is the staple in the diet for much of the world. It is the major source of carbohydrate in the diet. Due to its acceptance and versatility, rice has been used to prepare different processed ready to eat food that are easy to consume and tasty. One such processing technique is puffing, where the rice kernels are puffed using high temperature. The subject of puffing of rice in particular has major importance in food. This is one the oldest technique used to process rice. There is not much research done on the nutritive quality and digestibility of the puffed rice, especially from the varieties obtained from Telangana state. Hence, an attempt was made to puff six rice varieties of Telangana state and was then subjected to nutritional analysis.

The traditional way of processing was used to puff the rice varieties. Based on the results obtained by sensory evaluation of the six puffed rice, three best were selected and subjected to physico- chemical, nutritional qualities and shelf life studies.

All the six varieties were subjected to sensory evaluation. The three best suited varieties of puffed rice based on their overall acceptability were WGL44 (8.20), WGL283 (8.20) and RNR2458 (8.20). The variety that scored the least on overall acceptability was MTU1010 (7.4). Based on these results the three best accepted varieties were selected and then subjected to physico chemical analysis, nutritional analysis and shelf life studies.

The physico- chemical characteristics of the three accepted puffed rice were studied. WGL 44 variety was observed to have highest Length (16.73 mm), bulk density ($0.18 g/cm^3$) and volume expansion ratio ($1.50 cm^3$). This variety had lowest diameter (2.37mm), volume ($17.66\ cm^3$) and water absorption index ($4.65 g.g^{-1}$). The WGL 283

variety was observed to have highest diameter (3.84mm), texture (52.18N) and water absorption index ($6.66 g.g^{-1}$) and the lowest result was observed in length (10.68mm) and bulk density ($0.12 g/cm^3$). The RNR 2458 was shown to have highest volume ($25.41 cm^3$) and lowest score in texture (37.92N) and volume expansion ratio ($1.26 cm^3$). The whiteness of the variety WGL 44 was observed to be the highest (91.26) and lowest in the variety WGL 283 (85.86).

The proximate analysis was performed with three varieties of puffed rice. The moisture content of WGL 44 (1.37%) was observed to be highest and lowest moisture content in WGL 283 (1.15%). The highest total carbohydrate value was observed in WGL 44 (78.57g/100g) and lowest in RNR 2458 (75.50g/100g). The protein content was highest in RNR 2458 (6.58g/100g) and lowest in WGL 44 (6.33g/100g). The fat content was highest in WGL 44 (0.95g/100g) and lowest in RNR 2458 (0.92g/100g). The ash content was highest in WGL 283 (0.73%) and lowest in WGL 44 (0.23%).

The nutritional properties of puffed rice were evaluated where the dietary fibre and resistant starch were analysed. The dietary fibre was observed to be highest in WGL 44 (0.92g /100g) and lowest in RNR 2458 (0.88 g/100g). The resistant starch was observed to be highest in WGL 44 (2.29g/100g) and WGL 283 (2.23g/100g).

The In vitro digestibilities of the three varieties were carried out, to observe the digestibility of carbohydrate and protein. The in vitro carbohydrate digestibility in RNR 2458 (82.21 %) was observed to be highest and lowest in WGL 283 (80.28%). The in vitro protein digestibility in WGL 44 (86.30%) was observed to be highest and lowest in RNR 2458 (82.67%).

The shelf life of the three rice varieties was observed over a period of three months by observing their moisture content and by performing sensory evaluation. There was a change observed in the moisture content in all the three varieties over these three months. Whereas, few parameters like flavour, texture, mouth feel and overall acceptability showed significant changes over the storage period, while colour, appearance and taste did not show much difference in their score after the shelf life period.

The variety that was observed to be most suitable was WGL283, as it showed good texture, expansion ratio than others in its physical property. The nutritional analysis also found better results with WGL283 as the carbohydrate, protein and in vitro digestibility content was better than others. Due to less moisture content, it showed to have better shelf life and acceptability on sensory attributes.

INTRODUCTION

CHAPTER I

INTRODUCTION

Rice is the second most consumed cereal and has become the most important food source in Asian countries especially in south- east where it is an economic crop for many farmers (Arash, 2013). The cultivation of rice (*Oryza sativa.L*) by people began more than 10,000 years ago which led to development of rice culture over years, making it the staple crop for more than half of the world's population (Jerome *et. al*., 2008).

Asia accounts for about 90% of world's rice production of which China, India, Thailand, Indonesia, Myanmar, Bangladesh and Japan are major top ten rice producing countries. Rice production (2007-08) in India accounts for 96,430 million tonnes and of which Andhra Pradesh accounts for 132.26 million tonnes (CMIE, 2009).

Among the Asian Countries that contribute in the rice production, India stands a very important place as it has been one of the highest rice producing country in Asia. Though there has been a slight fall in the trend from the year 2014 due to the natural hazards and climatic conditions that effected the rice production in the country. The Asia's contribution in year 2013 was 675.8 million tonnes, the largest contributors being India, Indonesia and Pakistan. Whereas, by the year 2015 there has been fall in the rice production i.e. 667.8 million tonnes, India giving low contributions to rice production (FAO, 2015).

In India, rice is an important source of food as well as source of income to many families. The major rice producing states in India are West Bengal (16.39 %) that accounts for major contribution of total rice average followed by Uttar Pradesh (13.39%), Andhra Pradesh (12.29%) also includes Telangana state, Punjab (9.48%), Orissa (7.68%), Tamil Nadu (7.38%), Bihar (5.87%) and Madhya Pradesh (1.78%) (www.commodityIndia.com, 2003).

Rice is the largest commodity to the people as it is a part of our daily lifestyle. It contributes to be a major source for carbohydrate to the individual by supplying 60 percent of dietary intake. Among the many states in India, Telangana state has contributed largely to the supply of rice to the country. In the Telangana state, southern Telangana grows medium duration varieties while northern Telangana grows mainly short duration varieties and stand fourth for its rice productivity (Subaiyya, 2008).

Andhra Pradesh (including Telangana) is a surplus rice growing state, with cultivated area of 39.46 lakh ha and average productivity of 3352 kg/ ha during the year 2007- 2008 (ANGRAU Annual Report, 2007-2008). Rice is grown in almost all parts of the state in all seasons and in all kinds of soils, and is rightly called as "Annapurna state", "Rice bowl of India" and "Granary of south India". Rice is a dominant staple food for about 70 million people in the state and a major source of livelihood to nearly 70 percent of rural household and is consumed in many forms.

Snack food has become a very important and a growing food industry covering a lot of food groups. It's a complex process to plan and design new products that could meet the changing requirements of the consumer and make something unique and appealing to the target group. Puffing is one such process that is inexpensive, simple and is a traditional method of dry heat application which cause sudden release and expansion of water valour resulting in puffing of the grain (Sullivan and Craig, 1984).

A variety of rice products are produced in order to enhance the storage capability, easy cooking to instant cooking and provide new food with better nutritive value and flavour. Puffed rice becomes bases for many other convenient foods in the markets. Usually puffed rice is made from sundried paddy which has been moistened in hot water for some time. After keeping it in moistened condition it is sundried and parched in hot sand to puff the grain (Bhatia, 2008).

The rice varieties that are considered suitable for puffing should have low amylase content as high amylase content gives a low puffing index. The effects of puffing are also influenced by morphology and the composition of the kernel (Mariotti *et.al*., 2006). The size of the kernel, shape and density also effects the expansion ratio of the grain (Nirav *et.al*., 2014). It is also considered that addition of salt also affects the expansion ratio of the grains (Chinnaswamy and Bhattacharya, 1983).

Puffing of rice is an old method of processing done with rice; there are different methods that are followed to do so. There is some old traditional method that uses dry sand techniques and some new innovations in puffing industry were gunshot puffing, HTST (High Temperature Short Time) fluidised bed puffing and microwave puffing. These latest inventions in puffing machinery made puffed rice a more commercialized product in the market (Gayatri *et.al*., 2014).

The rice varieties that are usually preferred for puffing are high quality short and medium grain rice also known as "soft rice", as these cook moist and firm, and the cooked grains tend to stick or lump together (Bor, 1991) and these type of varieties are usually grown in Telangana state. Some tested rice varieties that were found suitable were some high amylose rice varieties from Tamil Nadu (Thayumanavan and Sadasivam, 1984).

Puffed rice along with taste impart some health benefits to the individual making it more effective for consumption. According to FAO (2006) consumption of puffed rice was suggested to reduce prevalence of disease risk. Due to the absence of gluten, puffed rice can easily take over the place other bakery foods which are source of gluten and can cause discomfort especially people with celiac disease (Prasad *et.al.*, 2010).

There are certain health benefits that are provided due to the process the rice undergoes, like the process of roasting where the rice starch gets damaged, gelatinized and subsequently a part of it is retro gradated, which leads to the formation of resistant starch, making it a type of pre- biotic food apart from conventional and nutritional low cost product for low income masses (Kumar and Prasad, 2013).

Puffed rice provides less calories compared to cook rice, making it a better option for those who are considering losing weight that is low in calorie and as well as nutritious. Puffed rice contain no cholesterol or sodium, making it suitable for everyone. It is known to provide minerals like potassium, iron, phosphorus, calcium and trace amounts of zinc, manganese, fluoride and selenium. It also provides vitamin B-thiamine, riboflavin, niacin, pantothenic acid (Chandramitra, 2013).

Puffing rice is a very useful way to utilise the high availability of rice in the country as it marks as an important source of nutrients especially to low income group population that cannot afford high end products. Telangana being one of the rice producing states of the country can use this simple puffing process to make nutritious ready to eat snack food or supplement food for a larger group of population. This simple technique of puffing adds variety and increase the shelf life of the cooked rice making it more appealing. As Telangana state is known to grow rice varieties that might be suitable for puffing process, it would be beneficial to experiment on few of the common rice varieties grown in Telangana for puffing and learn their nutritional component. Therefore, the present study was undertaken with the following objectives:

OBJECTIVES:

- To screen the selected rice varieties for puffing quality and to identify the best suitable varieties for the process.
- To analyse the physico - chemical, nutritional quality and resistant starch of puffed rice.
- To evaluate the sensory properties of the puffed rice.
- To conduct shelf life studies of the three best acceptable puffed rice.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Rice is one of the most important food crops in the world and the staple diet for nearly half of the world's population for more than 5000 years. High yielding varieties helped in achieving self- sufficiency, which also provided an access to enter into the international trade. Rice grain quality is of great importance after yield for all people involved in production, processing and consumption because it has different impact on the commercial value of the produce. An unattractive grain characteristics and unsatisfactory cooking quality hamper the acceptance and spread of varieties worldwide including India. (Shobha *et.al*., 2008).

The present study was on "Screening of Selected Rice Varieties for Puffing" was conducted at Department of Foods and Nutrition, Post Graduate and Research Centre, Rajendranagar, Hyderabad. Literature available relevant to present study has been reviewed under the following headings.

2.1. Production trends of rice

2.1.1. Global production of rice

2.1.2. Production of rice in Telangana State

2.2 Puffing process for rice

2.2.1 Parboiled rice

2.2.2 Different methods of puffing

2.3 Nutritional properties of Puffed Rice

3.3.1 Resistant starch

2.4 Other puffed products:

2.5 Packaging and shelf life of Puffed Rice

2.1. Production trends of Rice:

2.1.1. Global Rice Production:

About one billion households in Asia, Africa and the America depend on rice system for their main source of employment and livelihood. Viewing the importance of the rice, the United Nations Food and Agricultural Organization has declared the year 2004 as the **“International Year of Rice”.** Global production of paddy is increasing year after year which could be primarily due to India whose production is forecast to rise by 18%. Paddy product is expected to improve in the other Asian countries like Bangladesh, Myanmar, Pakistan, Philippines, Sri Lanka, Thailand and Vietnam. High production in these countries is expected to surpass the expected lowering of production in the countries like China, Japan and Republic of Korea and the major top ten rice producing countries during the year 2007- 2008 are given in Table. 2.1. China has shown to be the highest rice producing country in the world followed by India.

Table 2.1: Top 10 milled rice producing countries, 2007- 08.

Country	Production (MTs)
China	129.5
India	94.0
Indonesia	34.0
Bangladesh	28.4
Vietnam	23.3
Thailand	18.6
Myanmar	10.7
Philippines	10.4
Brazil	8.0
Japan	7.0

(www.CommodityIndia.com , 2005)

In 2010, the rice production was seen to be approximately 154 million ha worldwide, of which 137 million ha (88 percent of the global rice harvests) were in Asia- of which 48 million ha (31 percent of the global rice harvested) were harvested in Southeast Asia (FAO STAT, 2012).

The world rice production, according to FAO (2010) reports was 680.4 million tonnes. The production was reported higher in Asia, with the most important revision pertaining in India. A downward revision was shown in Bangladesh, China and Philippines. The rice production in Asia was shown to increase in 2010 to 614.3 million from 350,000 tonnes in 2009.

The world rice production has shown to an increase in its growth over years. The following table 2.2.shows the world production of milled rice over period of 8 years i.e. 2008-09 – 2015-16.

Table 2.2: Worldwide milled rice production from 2008/09- 2015/16.

Year	Production (million metric tonnes)
2008/09	448.2
2009/10	440.5
2010/11	449.3
2011/12	465.8
2012/13	471.9
2013/14	478.4
2014/15	478.2
2015/16	469.3

Source: Statista 2016 (www.statista.com)

The Table. 2.2. Shows that the rice production has increased overs years, especially in the years 2012 – 2014, where the rice production was seen to be highest. There has been a slight fall in the year 2014- 2015, further decreasing in the year 2015-16.

Rice is reported to be grown during three seasons in India i.e. autumn and winter or kharif or Rabi. Nearly 84- 86% of the rice is said to be produced during the kharif season (June- October) and the remaining is produced during the rabi season. India has great contribution in global rice production. The states that contributes to the country's rice production from 2008 – 2012 is shown in Table.2.3.

Table. 2.3: Top ten state production of rice in India from 2008- 2012: (million tonnes)

States	2008- 09	2009- 10	2010- 11	2011- 12
Andhra Pradesh	14241.0	10514.0	8645.0	11510.0
Assam	4008.5	3796.7	3115.9	5129.0
Bihar	5590. 3	3620. 7	3069.6	7529.0
Chhattisgarh	4391.8	4110.4	5293.8	6609.0
Karnataka	3802.0	3512.0	3193.2	3364.0
Orissa	6812.7	6895.0	5661.0	7295.0
Punjab	11000.0	11236.0	11000.0	11374.0
Tamil Nadu	5182.7	6024.0	5400.4	4050.0
Uttar Pradesh	13097.0	10792.1	12202.4	14416.0
West Bengal	15037. 2	14881.7	8320.0	15024.0
All India	99182.4	89127.3	80412.3	105232.0

Source: Directorate of Economics and Statistics, Ministry of Agriculture. (2015)

Every year the rice production statistics change, changing the position of the state in the ranking of the top ten states contributing most to India's production. The top ten states for rice production in India during the year 2012- 2013 are shown in Table 2.4. The change in the production trends makes West Bengal the highest rice producing state in India and Andhra Pradesh standing third.

Table. 2.4: Top ten rice producing states during 2012- 2013.

States	Rice Production (million tonnes)
West Bengal	15023.6
Uttar Pradesh	14416.0
Andhra Pradesh	11510.0
Punjab	11374.0
Bihar	7529.3
Orissa	7295.4
Chhattisgarh	6608.8
Assam	5128.5
Tamil Nadu	4049.9
Haryana	3976.0

Source: Directorate of Economics and Statistics, Ministry of Agriculture (2013)

2.1.2 Rice Production in Telangana State:

Andhra Pradesh is the fifth largest state in India accounting for 9 and 8 percent of the country’s area and population. The state comprises of three regions i.e. Telangana, Rayalaseema and Coastal Andhra. Agriculture being the basic mode for lively hood, different grains is grown in the State. Telangana state has shown improvements in growth in agricultural sector producing food grains to satisfy the demands of people. Table 2.6. shows area production and yield of food grains in Telangana state. The last ten years have shown to an increase in the production of rice though the yield has decreased for last two decades.

Table 2.6. Area, production and yield of food grains in Telangana State from the year 1973-2011.

Year	Area (hectares)	Production (million tonnes)	Yield (hectares)
1973/74- 1982/83	-0.76	3.22	4.01
1983/84- 1990/91	-2.86	2.29	5.30
1991/92- 2000/01	0.23	4.58	4.21
2001/02- 2010/11	1.12	5.87	4.84
Total	-0.88	2.68	3.59

Source: Department of Economics and Statistics data. (2011)

Among the different food grains that are grown in the state, rice has been giving highest contribution in the agricultural growth. Though there has been decline in food crop production over years, there has been visible improvement in rice production over years. The following table 2.7.shows the food grains and its production over years (million hectares).

Table 2.7. Grains and its production over years in Andhra Pradesh (million hectares).

Year	Rice	Maize	Pulses	Total grains
1970 -73	3.1 (24.76)	0.2 (2.12)	1.3 (10.79)	8.9 (70.42)
1987- 90	3.9 (30.65)	0.3 (2.33)	1.5 (11.85)	7.8 (61.31)
2004- 07	3.6 (28.54)	0.7 (5.33)	1.8 (14.39)	6.9 (53.52)
2009- 11	4.3 (31.15)	0.8 (6.16)	1.7 (12.3)	7.4 (53.6)

Source: Department of Economics and Statistics, Government of Andhra Pradesh. (2011)

Rice is now the dominant cereal in the State. Telangana experienced a higher growth in food grain output showing higher growth during the last two decades. Rice being the staple food of the state is grown in different districts of Telangana. Table 2.8.

Shows district wise area, production and yield of rice in specific in Telangana state during 2003-2004.

Table 2.8. District wise area, production and yield of Rice in Telangana state during 2003- 2004.

Districts	**Area (in hectares)**	**Production (in tonnes)**	**Yield (in kg/ ha)**
Adilabad	80920	200748	2481
Karimnagar	187576	602047	3210
Khammam	142108	412482	2903
Mahbubnagar	99496	230606	2318
Medak	86303	216005	2503
Nalgonda	123009	358144	2912
Nizamabad	91370	282358	3090
Ranga Reddy	36299	85547	2357
Warangal	170235	510766	3000

Source: Consortium of Indian Farmers Associations (2010)

Rice is available in different varieties world-wide. Usually medium grain rice is grown in Telangana state. The highest producing district is Karimnagar followed by Warangal. Hyderabad being a metropolitan city, its involvement in agriculture is negligible.

2.2. Puffing Process for Rice:

Lifestyle changes, food habits and urbanization have increased the demand of processed food in India. Convenient snack foods like popcorn, popped and puffed rice, popped sorghum, popped wheat roasted and puffed soybean are very popular in India and worldwide (Jayabhae *et.al*., 2014).

Rice being major source of calorie consumption, rice has been processed to develop instant rice products like puffed rice, rice flour starch etc. The keeping quality of the rice is increased for these products. The physical properties of puffed rice are depended on the moisture content of the grain and is directly proportional to puffing quality (Basavaraj *et.al*., 2015).

Puffed rice is a whole grain product from pre-gelatinized milled rice, is one of the convenient rice based popular products consumed in the rice growing countries. It is a major source of carbohydrate (89%), protein (5- 9%) and other beneficial nutrients, i.e., dietary fibre, vitamins, minerals and phytochemicals, which have been known to have health benefits (FDA, 2006).

Maisont and Narkrugsa (2009) studied the impact of amylose content on the puffing characteristics of rice. The results indicated that the amount of amylose content present in the rice negatively correlated the qualities of the puffing. The rice paddy suitable with suitable physico chemical characteristics of puffing had low amylose content.

The presence of amylose not only effects the puffing quality of the puffed rice but it also effects the aging of the products and that brings undesirable changes in the puffed rice quality. Rossaporn *et.al*.(2015) study indicated that the higher amylose content and aging time resulted in higher hardness, facturability, crispness and bulk density, but lower expansion ratio and less oiliness of the puffed product.

Rice puffing includes parboiling, drying, milling and roasting process. Traditionally paddy is parboiled or gelatinized by hydrothermal treatment before puffing. The hydrothermal treatment may include only hot water soaking and steaming or sand roasting of moistened grains (Hoke.*et.al*., 2007).

2.2.1. Parboiling of rice:

Parboiling of paddy rice is one of the post harvests processing of rice which is commonly employed for quality maintenance. More than 75% of rice farmers in Nigeria still employee the traditional method of parboiling of rice. There are a number of modern and traditional processes have been used to parboil rice in different countries. Each method is an attempt to improve grains, the technology or equipment used to soak, steam and re- dry paddy (Oyenuga, 2006).

Parboiling of rice is a conditioning process of rice that is done before heat processing of the rice. The conditioning process involves slow and medium heating of soaked high moisture rice coupled with turning or agitation before puffing is the most critical factor for obtaining good quality of puffed rice. Pre conditioning of rice continues till the hardness of the rice is achieved between 44-47N and the final moisture content is 10% (Mohapatra and Das, 2011).

Parboiling with addition of salt gave positive results in puffing. It was observed that salt appreciably increased the expansion ratio. It was also observed that not only Sodium chloride but also other salts had the same effect. Salt helped the expansion by facilitating the heat conduction inward and moisture outwards (Gerkens and Daranaud, 1993).

Parboiled rice is known to have a number of advantages, require more energy, water and time for processing and cooking than the untreated rice. The parboiling treatment gelatinizes the rice starch, improves the hardness of the rice upon drying, minimized the breakage loss and thus increases the milling yield (Ali and Pandya, 2005).

The parboiling process brings in physical, chemical and nutritional changes in rice. The milling yield is higher and quality is improved as there are fewer broken kernels. The preservation of parboiled paddy and milled rice is longer and better than raw in the raw state. Germination is no longer possible and makes its resistant to micro-organisms. The milled rice remains firm during cooking, and its texture becomes unsticky. Increased water absorption causing rice to swell, the nutritive value is also improved (Kazuhiko *et.al*., 2005).

Parboiling increased the milling quality of rice, particularly the long grained varieties resulting in a greater yield of head rice. However, the polishing of rice was extended beyond 20%, parboil rice tend to break up more than raw rice and then gave a lower yield of head rice (Subhramanya *et.al*., 1990).

Parboiling of rice has been proved to be very beneficial by many researchers. Dutta and Mahanta (2014) concluded that milled parboiled rice gave mineral expansion, which increased with increasing severity of parboiling up to a steam pressure of 1.5kg/cm^2 for 10 min. The study revealed that good expanded product produced, when the paddy was soaked for minimum of 45 min at 80^o C before steaming.

Parboiling shows an effect on the presence of crystallized amylose in the rice. It was observed that, the parboiling process effect the crystalline amylose content in rice. The mildly parboiled rice showed un-gelatinized amylose and amylose crystalline was observed in intermediate and severely parboiled rice (Lieve *et.al*., 2009).

On parboiling the nutritional content of rice was affected. In a comparative study conducted by Heinemann. *et.al*. (2005), it was observed that the ash content was increased to 18% in parboiled rice than normal milled rice. Parboiled rice also showed increased amount of phosphorus and potassium, whereas, manganese, calcium and sodium were slightly less in comparison.

In parboiling of rice a range of factors (genetic makeup and environmental) combines to affect the quality of rice. The factors that can affect the quality of the parboiled rice also include the way the crops are handled from the point it is harvested to its storage. (Virmain *et.al*., 1978).

Effects of parboiling on physico- chemical qualities were studied by Otegbayo *et.al*.(2001), the results indicated that parboiling reduced the breakage, fat, protein and amylose content of the rice of the rice while the cooking time, water uptake and thiamine contents were increased.

The effect of parboiling on the nutritional composition of the rice is a topic of interest for many researchers. In a study by Swaminathan (1941) indicated that the amount of vitamin B1 was more in parboiled milled rice than raw milled rice. The loss was measured to be 60% in raw milled rice and the loss of vitamin B1 was less than 8% in parboiled milled rice. Even after washing parboiled milled rice contained 8- 9% more vitamin B1 than raw milled rice. Cooked parboiled rice, even after discarding the cooking water contained more than minimum of vitamin B needed to prevent Beri-Beri.

It is important to maintain condition of parboiling to prevent over- parboiling of rice. Over- parboiling results over- opening of the husk components followed by bulging out of the endosperm which initiates surface scouring during milling and the resultant ground particles are lost into the husk and bran. Incomplete or non- uniform parboiling produces white- bellied rice, which breaks easily during milling, and rescue the head rice yield (Mecham *et.al*., 2010).

2.2.2. Different methods for puffing:

Puffed snacks are produced by submitting grain to high temperature and high compression. The principle process involved is the phase- change of starch at high temperature and high compression (Huff *et.al*., 2008). The increase in rice content led to greater specific volume, hardness, and lighter colour as puffing expansion is very highly correlated with starch changes (Mahanta and Bhattacharya, 2010).

Puffing can be accomplished by using dry heat such as sand roasting, roasting using salt, gun puffing, hot oil frying, and using heat medium such as hot air or microwave radiation. In India, the most frequent way is, puffing in hot sand (temperature of sand is about 250^{o} C) in oil (200- 220^{o} C) (Jayabhaye *et.al*., 2014).

In a study done on Bengal gram, Pratare and Kurlien (1996) roasting of grains was done with sand at 170^{o} C for 75sec was carried out followed by tempering the grains for about 90 minutes to reach the moisture content of about 14.9% (wb). The tempers grains were then dipped in water for 5sec and impacted between a roller and a hot plate for de- husking and splitting. Under these conditions the bulk volumes of grains doubled during puffing.

Gun puffing is a process in which the milled grains are introduced in to the gun or high pressure chamber after pre heating, and then a superheated steam is introduced to the closed rotating chamber. The steam pressure is critical to the final texture of the puffed product, as too low pressure would result in product lacking crispiness and too high pressure would shatter the rice. Sufficient time is allowed for the super heated steam to cook the grain in semi- plastic state and in the end, the pressure is suddenly released for obtaining the crispy puffed grain (Luh, 2001).

Keesenberg (1978) developed a puffing gun, which was composed of rotating horizontal cylinder having the length of 1.2m and the inner diameter of 200 mm, the cylinder was closed on one side and the steam inlet is placed at this point. On the opposite side a heavy cast iron lid was placed. When the structural characteristics of pre- gelatinized rice flour produced by gun puffing compared with hot air puffing method for three varieties and found that gun puffing method resulted in structural disintegration of starch granules, which is affected the pasting properties.

Mariotti *et.al*. (2006) conducted a study on different grains to learn the changes associated with gun puffing. It was observed that puffed rye and rice had a very porous matrix, made up of numerous cavities of different sizes separated by very thin wall puffed wheat.

According to the process used by Nath *et.al*. (2007), the raw material is heated in an enclosed vessel so that its vapour creates a high pressure atmosphere around the product. The pressure is suddenly released, so that the products explode due to evaporation of moisture from within. This evaporation cools the product and its temperature drops to possess solid like behaviour. The main parameters affecting are puffing temperature, puffing duration, initial moisture content of the material to be puffed, and starch content of raw material.

Fluidization is known to increase the heat and mass transfer as product surface area is uniformly exposed to the heating medium, therefore, fluidized bed high temperature short time (HTST) puffing is more efficient than hot air or conduction roasting or puffing process (Venkatesh *et.al*., 1989).

Surface heat surface coefficient is an important parameter in fluidized bed puffing. The temperature ranging from 240^{o} C to 270^{o} C with corresponding exposure time of 7 to 9.7 s was found to be optimum for higher expansion ratio and better colour of the product (Chandrashekhar and Chattopadhya, 2004). According to Konishi *et.al*. (2004), the resultant grains were observed to be influenced by the moisture content, and also by the moisture in the heating media.

A different method of processing used for puffing is microwave puffing. The use of microwave energy in food processing has evolved and now is an established phenomenon as a source of clean thermal energy and has a promising potential of cooking, tempering, drying, heating, baking, blanching, popping and puffing process (Roussy and Pearce, 2005).

Moisture is the driving forces in microwave heating, glassy starch simultaneously lose moisture and expand. The degree of gelatinization and moisture content of the starchy grains were two of the most important factors in determining the shape, expansion bulk volume, density and puffing quality of the microwave products (Ernoult *et.al*., 2002). Moisture should be maintained at appropriate level as very low or very high level of moisture may not cause proper puffing of the grain (Lee *et.al*., 2000).

In microwave expansion of the cereal grains, the microwave energy heats the product through the vibration energy imparted on moisture. Upon heating, moisture generates the superheated steam necessary for expansion, which accumulates at the nuclei in the glassy matrix, creating a locally high pressure. Under high superheated steam pressure the expansion takes place. As the moisture is lost, upon cooling the matrix revert to the glassy state and the final structure sets (Madhuri, 2002).

Microwave process parameters such as microwave power level, microwave power density and residence time are major factors deciding the puffing quality of the cereals in microwave (Sweley *et.al*., 2012). Physical properties that affect the puffing quality of rice include husk interlocking, presence of white belly in the grains, husk content, hydration capacity of paddy and percentage of cracked kernels (Srinivas and Desikachar, 1993).

2.3. Nutritional Properties of rice:

Rice (*Oryza sativa L.)* is the staple food for most of the world's population, providing as much as 75% of the daily calorie intake of the people in some countries of Asia (FAO, 2001).

Rice properties depend on the varieties of the rice, methods of cultivation, processing and cooking conditions. Parboiling is one such technique that helps in retaining some of the nutrients, reduce breakage loss during milling and increase head rice recovery. But the nutritive qualities and the head rice recovery reduces with higher degree of milling (Juliano, 2005).

The protein, fat, vitamins and minerals of the rice are usually concentrated in the germ and outer layer of the starchy endosperm which are often lost during milling. Health consciousness has led to consumers opting for low degree of milling or brown rice, as the nutritive content is retained (Itani *et.al*., 2002).

Milling of rice, remove the bran and husk giving the edible portion of the rice. The nutrient content of the milled rice depends on the variety of the rice taken. In the 258 diverse varieties of rice, the protein content ranged from 4.91% to 12.08%, similarly wide variations were recorded in lysine content of the rice varieties (Banerjee *et.al*., 2011).

Joanne *et.al*. (2000) through his studies conducted in animal models and human models suggested that milling of grains concentrates the desirable grains components and removes poorly digested compounds and contaminants. While cooking of grains increases the digestibility of the nutrients and phytochemicals.

Milling process remove large amount of phytate which might otherwise effect the utilization of some trace elements especially zinc. Fibre which might affect the digestibility of the protein is also removed during milling (Roxas *et.al*., 2002).

In a study by Marlene *et.al*. (2005), it was learned that consumption of rice bran oil showed low blood lipids in men and women with borderline high total cholesterol and though the results did not show effects in the triacylglycerol.

It is well known that the nutrient content of brown rice comparatively better to highly milled rice. In highly milled white rice the protein content was reduced to 86% and the mineral content 23% compared to brown rice (Birthe and Eggum, 2003).

Brown rice is considered better than white as it showed great effect on weight loss, by showing decreased weight parameters in 8 weeks. Its consumption also reduced the insulin resistance and LDL cholesterol level, some long term beneficial effects of metabolic parameters and endothelial functions were also observed (Machio *et.al*., 2014).

Rice is usually parboiled; especially for any rice based products as parboiled rice are considered to give a better cooking quality. Parboiling helps to retain and gives better distribution of the nutrients. Yeshwant *et.al.* (2006) proved that parboiling has altered the distribution of certain nutrient except zinc, magnesium and copper and the significant loss of nutrients were less in parboiled rice than the raw milled rice.

Table 2.9. Nutritive value of parboiled rice (per 100g)

Nutrients	**Value**
Calorie	123 kcal
Carbohydrates Dietary fibre Sugars	26.0 g 0.9 g 0.1 g
Protein	2.9 g
Total fat Saturated fat Monounsaturated fat	0.4 g 0.1 g 0.1 g
Vitamin A	0.0IU
Vitamin C	0.0 mg
Thiamine	0.2 mg
Iron	1.8 mg
Phosphorus	55 mg
Potassium	56 mg
Sodium	2.0 mg

Source: USDA

Rice is always considered as a high glycemic index food. A study by Miller *et.al.* (1992) suggest that irrespective of the variety of rice and the type of rice i.e. brown rice, parboiled rice or even rice products are considered to high glycemic foods and only low amylose varieties are potentially useful as low glycemic index food.

In a study by Paritosh *et.al.* (2011), Brown rice, germinated brown rice and partially milled rice contains more beneficial food components compared to that of well milled rice. The risk of arsenic contamination was reduced in brown rice and partial brown rice.

Parboiling being an ancient method of rice processing has been a part of rice processing for many years and by many countries. Parboiling treatment induces physico chemical changes in the paddy which plays a vital role in the increasing storage, milling, cooking and eating qualities (Roy *et.al*., 2007). Hence parboiling has become an important step in any processed rice snack.

Parboiling the rice makes many desirable changes in the rice properties giving different physico chemical properties and texture to the rice based products. As parboiling treatment gelatinize the starch, improves the hardness of the rice upon drying, minimized the breakage loss and thus minimize the milling yield (Roy *et.al*., 2004).

Puffed rice are commonly used as ready to eat breakfast or as a snack. Puffing makes the grain matrix more porous and their puffing characteristic is defined by the composition and morphology of the kernel and includes significant changes in structure and physical properties of starch and water holding capacity (Mariotti *et.al*., 2006).

2.3.1. Resistant starch:

Resistant starch is the undigested starch that escapes digestion in the small intestine and on reaching the large intestine acts as dietary fibre. Dietary fibre has subtypes based on their digesting properties (Murphy *et.al*., 2008).

Starches that resist small intestinal breakdown are fermented by the bacteria in the large intestine, producing a variety of end products including short chain fatty acids (SCFA) that provides a wide range of physiological benefits (Topping and Clifton, 2001).

Resistant starch has great physiological benefits and is known to provide better digestive health. The short chain fatty acids that released along with resistant starch provide good intestinal health (Weaver *et.al*., 1992). Adding to the benefits, it contributes to the intestine is the protections to the colon cells present in the intestine as it prevents the degradation of the mucous layer within the colon that in turn protect the colon cells (Toden *et.al*., 2006).

Resistant starch is known to the best substrates for the production of butyrate that is one type of short chain fatty acid that is considered to be required for necessary physiological changes. Resistant starch is known to produce twice the amount of wheat fibre and four times more than pectin (Champ, 2004).

In a study by Redlon and Heylmon (2006), resistant starch rich diets showed a link with colonic bacteria and colonic caner. The results of the study indicated that high resistant starch diets may prevent colon carcinogenesis.

According to FAO (2006) consumption of puffed rice was suggested to reduce prevalence of disease risk. Due to the absence of gluten, puffed rice can easily take over the place other bakery foods which are source of gluten and can cause discomfort especially people with celiac disease (Prasad *et.al*., 2010).

Resistant starch is known to bring in satiety and is considered beneficial in weight loss programmes. Anderson *et.al*. (2010) studied a relationship between resistant starch and satiety, and showed 15 % reduced cumulative food intake on consumption of high resistant starch containing food.

Processing of food grains is commonly known to alter the bioavailability of both macro and micro nutrients. Damaged starch and resistant starch (RS) are the outcome of such processing treatment. The content of the resistant starch is found to be different in different processed rice products, which accounted for their easy digestibility compared to raw rice. The puffed rice showed reduced amount of amylose content (Mahadevamma and Tharanathan, 2007).

The property of the food changes varies in their significance taste and nutritional value, macro and microstructure of the product and starch digestibility of the product during processing. The extent of starch gelatinization and retro gradation which takes place during processing is an important factor in the formation of undigested starch and its subsequent responses. As per the study done by Silanere *et.al*. (1999), the amount of resistant starch present in processed rice products was observed to be higher than the finger millet processed foods.

Cereals, millets and legumes are the most consumed food groups in India. These food groups are highest in starch content and this on heat processing forms resistant starch. Platel and shurpalekhar (1994) studied the resistant starch content of the various cereals, millets and legumes based processed food. It was observed that among the rice based processed foods, dry heat processed rice products (puffed and popped rice) had higher amount of resistant starch (i.e. 2.22g and 2.32g respectively) than wet processed rice products (i.e. 1.17g).

2.4. Other puffed products:

Malleshi and Desikachar (2001) studied the optimal conditions for puffing of ragi which were moistened to 19% moisture and equilibration for 4 h, followed by puffing in sand to 270°C. Wide varietal variation has been found in the puffing quality, among the fourteen varieties studied. No consistent relationship was observed between the grain in amylose, protein content or thickness of bran with puffing quality.

Novel process for ready to eat (RTE) foods based on minor millet like barnyard millet, finger millet and tubers like potato and sweet potato was developed using microwave puffing method by Dhumal *et al.* (2014) employing response surface methodology. They reported that the estimated shelf life of the final product based on accelerated storage studies at 95% relative humidity and 40 °C could be of one month, while the product could be well stored for 2 months in 65% RH and 6 months in 35% RH at 30 °C, after packing in 150 g metalized polyester.

The soy fortified wheat based flat cold extrudate, after requisite steaming, was puffed in hot air using the HTST whirling bed puffing system (Pardeshi *et al*., 2014). The product temperature attained by wheat-soy snack foods was about 110-111 °C to initiate puffing effect at all the puffing temperatures while the puffing time required to initiate puffing reduced from 20 s at 200 °C to 10 s at 240 °C. Further the reports suggested that the average material temperature attained for wheat-soy snack Sorghum Cleaning Soaking in water for 150 min Surface drying (for 10 min) Puffing (21% M.C, wb; microwave level of 80%; for 2.5 min) foods to reach the optimum puffing effect reduced with increase in puffing air temperature.

2.5 Packaging and Shelf life of Puffed Rice:

Selection of packaging materials is based on the type of food to be packaged, intended shelf life of the product and also the target group of the consumer. A large variety of packaging materials are available such as metal, glass bottles, plastic laminates of food grade quality (Paranjpe, 2001).

The primary function of any food package includes containment, protection, convenience and communication. The secondary functions of food package include formation providing a giving an appropriate brand to the product (Paranjpe, 2001).

The moisture level of the puffed rice has to be reduced to 1-2 % to give desired crispness. The major mode of deterioration for extruded and puffed snacks is loss of crispness. A package which provides a good barrier to water vapour is the primary requirement. Extruded and puffed snacks are comparatively less sensitive to oxygen than juice snack foods and the oxygen requirement of the packages is consequently less stringent (Laskshmi *et al*., 2009).

Physical breakage of most cereals and snack foods is unacceptable to consumers. Many snacks foods are very fragile because they are fried, extruded, or dried from natural products. Many cereals and snack foods are protected by paperboard or plastic cases. The rigidity of printed fibre board (PFB) for cereal packaging and the compression resistance of the finished package seem to resolve the problem of physical breakage (Hsieh *et al*., 2005).

Crispiness is an essential characteristic of dried cereal foods. It is affected by the moisture content of the products, which is strongly related to the shelf life of products. Packaging materials for cereals are combined with PFBs for outer packaging and plastic films for inner packaging. Plastic films layers have been used to improve both moisture barrier and seal performance. To keep the desirable aroma and flavour in dry foods, and also to prevent external odour absorption, gas barrier materials and gas substitution have been utilized effectively (Safa *et al*., 2008).

Many cereals and snacks products are dry and contain lipids. They are stable against microbial growth due to their low water activity (a_w <0.6), but not against chemical and enzymatic reactions that result in product deterioration. The most important modes of deterioration in cereal products and snacks are loss of crispness (moisture uptake) and lipid oxidation causing rancidity or off- flavours (Labuza, 1990).

Many extruded and puffed snack foods are packaged in the same packaging materials used for fried snack foods. The major mode of quality deterioration of extruded/puffed snacks is loss of crispness, a package that provides a good water vapour barrier is the primary requirement. Some extruded and puffed snacks are comparatively less sensitive to oxygen than are fried foods, and the oxygen requirements of these packages are consequently less important than those of fried snacks (Robertson, 2006).

To maintain the crispness of the puffed products it is important to maintain low oxygen in the packed product. Low oxygen content may be achieved by vacuum packaging, flushing with N_2 or CO_2, or using O_2 absorbers in combination with low oxygen transmission rate (OTR) materials (Jensen *et al*., 2003).

MATERIAL AND METHOD

Chapter III

MATERIALS AND METHODS

The present study "Screening of Selected Rice Varieties for Puffing process" was conducted in the Department of Foods and Nutrition, Post Graduate and Research Centre, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during the year 2015- 2016.

This chapter includes detailed description of experimental procedure of the study under the following heads.

3.1 Procurement of raw materials

3.2 Puffing process

3.3 Evaluation of the sensory quality characteristics of rice varieties

3.4 Assessment of physical quality characteristics

3.4.1 Measurement of colour

3.4.2 Measurement of texture

3.4.3 Measurement of length and diameter

3.4.4 Measurement of volume

3.4.5 Measurement of Mass

3.4.6 Measurement of Bulk density

3.5 Assessment of functional quality characteristics

3.5.1 Measurement of volume expansion ratio

3.5.2 Assessment of water absorption index

3.6 Assessment of nutritional composition

3.6.1 Estimation of moisture

3.6.2 Estimation of carbohydrate

3.6.3 Estimation of protein

3.6.4 Estimation of fat

3.6.5 Estimation of ash

3.6.6 Estimation of dietary fibre

3.7 Assessment of Resistant Starch

3.8 Evaluation of In- vitro digestibility

3.8.1 In- vitro carbohydrate digestibility

3.8.2 In- vitro protein digestibility

3.9 Shelf life studies of puffed rice

3.9.1 Moisture content of stored product

3.9.2 Evaluation of the sensory characteristics

3.10 Statistical analysis

Detailed procedures are given below

3.1 PROCUREMENT OF RAW MATERIALS

3.1.1 Rice (*Oryza sativa*)

Six varieties of rice (*Oryza sativa*) viz WGL-44, WGL- 283, RNR 2485, MTU- 1010, MTU- 10001, JGL-11118 were procured from Agricultural Research Station, Rajendranagar, Hyderabad.

The samples were initially cleaned to remove foreign materials such as dust, dirt, grit and hollow grains.

3.2 Puffing Process:

A standard traditional method of puffing was used to puff the rice varieties. The rice was cooked first using the traditional method, where rice was soaked in water for 30 min and boiled or steamed to obtain whole grain cooked rice, where an equal amount of water was added to the milled rice, which was soaked at room temperature for two hours and then steamed at 18 psi pressure for 10 min. The water-rice was controlled to prevent the cooked rice from becoming too sticky and soft. Heating was controlled to ensure gelatinization of the rice grain. The cooked rice was dried to 10-12% moisture and fried in oil at 220^{o} C (428^{o} F) for 4- 8 seconds in a deep fryer. Then, the puffed rice was packaged. (Edmund and Lloys, 2002). Fig 3.1. shows the flow chart for preparation of puffed rice.

3.3 EVALUATION OF THE SENSORY QUALITY CHARACTERISTICS OF RICE VARIETIES:

All the six puffed varieties were subjected to sensory evaluation, Appendix-I contains the score card for evaluating all the six varieties. The sensory quality evaluation was conducted with a panel of 10 members consisted of residents of Redhills area, who were mostly from age 25- 40 years. All the six samples were coded using random three digit numbers. They were given instructions and asked to evaluate the products for acceptability based on its colour, appearance, flavour, taste, texture and overall acceptability.

Based on the results, three best accepted rice varieties were analysed for physico- chemical, functional and nutritional properties. The quality evaluation was done for the three best accepted puffed products prepared with RNR- 2458, WGL-44 and WGL- 283.

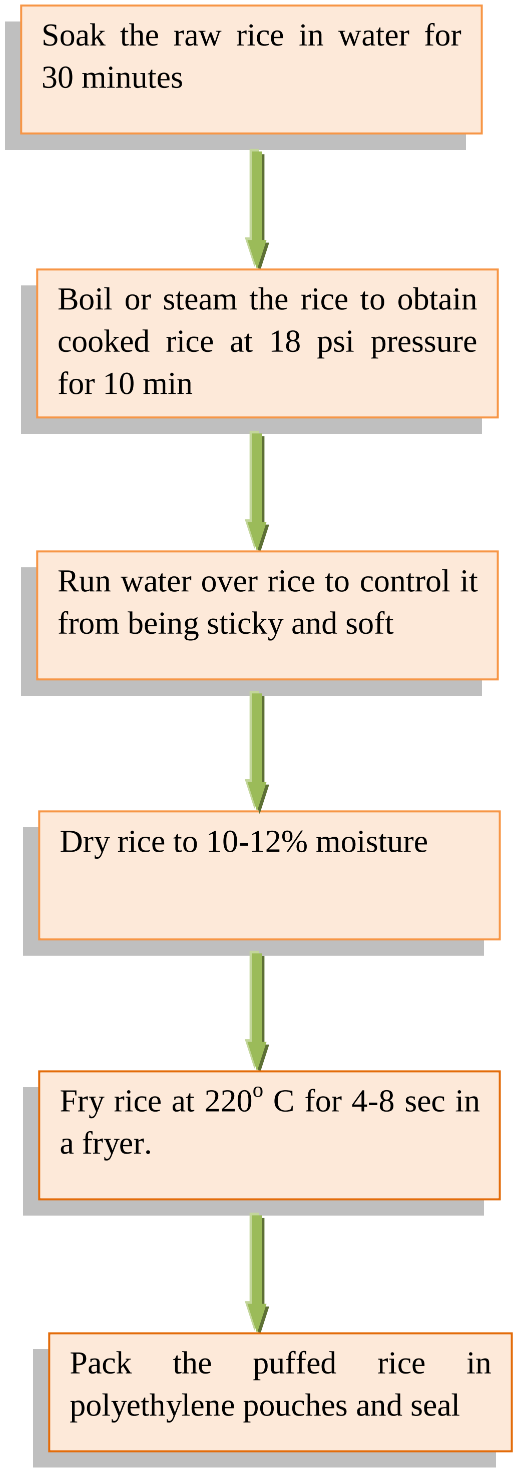

Fig. 3.1. Process flow chart for preparation of puffed rice

3.4 ASSESSMENT OF PHYSICAL QUALITY CHARACTERISTICS

The physical quality characteristics such as colour, texture, length, diameter, and volume and bulk density were assessed as detailed below

3.4.1 Measurement of colour

The colour measurement of the puffed rice products were carried out using a colour measuring system (Hunter colour lab, colour flex 45/0). A glass cell containing the powdered puffed rice was placed above the light source and coloured with a white plate and L*, a*, b* values were recorded. Where L* indicates lightness and extends from 0.0 (black) and 100.0 (white). The other two co-ordinates a* and b* represents redness (+a* value) to greenness (-a* value) and yellowness (+b* value) to blueness (-b* value) (Hunter, 1966).

3.4.2 Measurement of texture

The texture of the puffed rice products were measured by using a texture analysing machine i.e. Shimandzu EZ test texture analyser. The Karmer shear cell present in the machine is specialized to perform compression, shear and extrusion test (Singh *et.al.*,2001)

3.4.3 Measurement of Length and diameter:

Length and diameter of the puffed rice was measured in millimetres using a digital Vernier callipers, Yamayo digimatic calliper (Singh *et.al.*,2001).

3.4.4 Measurement of Volume:

Volume was calculated from expression $\pi r^2 h$. Dimension of the length (cm) and diameter (mm) were measured using a digital vernier callipers and an average of 10 readings were taken for each formulations (Singh *et.al*., 2001). The formula used is given.

$$\text{Volume} = \pi r^2 h.$$

3.4.5 Measurement of Mass:

The mass was calculated using electric balance and is measured in gms.

3.4.6 Measurement of Bulk density:

Bulk density was determined by filling one litre measuring cylinder with puffed rice slightly above the litre mark. The cylinder was tapped 10 times till the product measured up to one litre mark (AOAC, 1990).

The weight of the puffed rice was taken and bulk density was calculated:

$$\text{Bulk density} = \frac{\text{Weight}}{\text{Volume}}$$

3.5 ASSESSMENT OF FUNCTIONAL QUALITY CHARACTERISTICS

3.5.1 Volume expansion ratio

The volume expansion ratio was measured after processing through Chinnaswamy and Bhattacharya method (1984).

The expansion ratio is the ratio of the total puffed volume (ml) to that of volume of the raw kernels (ml) and expressed as ml.

$$\text{Volume Expansion Ratio} = \frac{\text{Total puffed volume (ml)}}{\text{Volume of raw kernels (ml)}}$$

3.5.2 Water absorption index

The water absorption index of puffed rice products were determined by the method given by Anderson *et.al. (*1969). One gram of dried puffed snack powder was accurately weighed and suspended in 6.0 ml of distilled water and shaken in water bath at 80^{o} C for 30 min. The content was centrifuged at 2,500 rpm for 10 min. The supernatant was carefully poured into an aluminium dish (of known weight) before drying at 105^{o} C for 10h and weighed. The sediment was collected and weighed. The water absorption index was calculated as:

$$\text{Water absorption index} = \frac{\text{Weight of the wet sediment (g)}}{\text{Dry weight of flour (g)}}$$

3.6 ASSESSMENT OF NUTRITIONAL COMPOSITION

The following nutrient analysis was done for the puffed rice varieties prepared with RNR- 2458, WGL- 44 & WGL- 283.

3.6.1 Estimation of Moisture (AOAC, 2005)

Moisture and water content are among the most important parameters measured in food. The content of moisture is inversely related to the dry matter of a food item. Hence there are direct economic effects on consumers and processors. More importantly, the moisture content in food also influences its stability and quality.

A petridish was weighed with lid (W1) and approximately 10g of sample was weighed into it and weighed again (W2). Petridish along with the sample was dried in an oven at 100- 105^{o} C for 15- 17 h and cooled in a desiccator and weight was noted (W3). The same process was repeated till constant weight was obtained.

Calculation:

$$\text{Moisture (\%)} = \frac{(W2 - W1) - (W2 - W3)}{(W2 - W1)} \times 100$$

3.6.2 Estimation of carbohydrate:

The total carbohydrate content of the processed sample was determined, using AOAC (1996). The detailed procedure is given in the Appendix -II

3.6.3 Estimation of protein

The protein content of the processed sample was determined, using the method of AOAC (2005). The detailed procedure is given in the Appendix- III

The amino nitrogen in various nitrogenous compounds in biological samples get converted in to organo nitrogen in Leco analyzer, there by protein content is arrived.

3.6.4 Estimation of fat

The fat content of the processed samples processed was determined, using the method of AOAC (1981). Fat is extracted as crude ether extract of the dry material. The detailed procedure is given in the appendix- IV.

Calculation:

$$\text{Fat content (g \%)} = \frac{W_1 - W_3}{\text{Wt of the sample}} \times 100$$

3.6.5 Estimation of ash content:

Foods and food products are heated to temperatures of 500 – 600 ^{o}C, where the water and other volatile constituents evolve as vapours and the organic constituents were buried in the presence of oxygen to carbon dioxide and oxides of nitrogen and eliminated together with hydrogen as water. The mineral constituents remain in the residue as oxides, sulphates, phosphates and chlorides. The inorganic residue constitutes the ash of food products. The ash content of the sample was determined by using the method of AOAC (2005). The detailed procedure is given in the Appendix- V

Calculation:

Weight of the sample taken = $W_2 – W_1$

Weight of the ash = $W_3 – W_1$

$$\text{Ash \%} = \frac{\text{weight of the ash}}{\text{Weight of the sample taken}} \times 100 = \frac{W_2 - W_1}{W_3 - W_1} \times 100$$

3.6.6 Estimation of dietary fibre

Dietary fibre is assessed by method of AOAC 1990. The detailed procedure is given in the Appendix- VI.

Calculation

$$\text{TDF \%} = \frac{\text{Mg residue} - [(\text{\% protein in residue} + \text{\% ash in residue}) \times \text{mg residue}] - \text{Blank} \times 100}{\text{Weight of the sample in mg}}$$

3.7 ESTIMATION OF RESISTANT STARCH

The estimation of resistant starch present in the puffed rice was determined using AOAC, 2002 method. The detailed procedure is given in the Appendix- VII.

Calculation

RS (g/100ml) (sample containing > 10% RS):

$= \Delta E * F/W * 90$

RS (g/100ml) (sample containing <10% RS):

$= \Delta E * F/W * 9.27$

Where,

ΔE= absorbance read against reagent blank

F= conversion from absorbance to µg

W= dry weight of sample analysed.

3.8 IN- VITRO DIGESTIBILITY

The invitro carbohydrate and protein digestibility of three rice puffed products were estimated by the following procedures.

3.8.1 In- vitro carbohydrate digestibility

The ability of the sample to inhibit alpha- amylase activity was determined by the method given by Englystelal (1992). The detail procedure is given in Appendix- VIII

3.8.2 In- vitro Protein digestibility

The digestibility of rice puffed products was determined by the method Aboubacar *et.al.*, 2001. The detail procedure is in the Appendix- IX

3.9 SHELF LIFE STUDIES OF PUFFED RICE:

3.9.1 Moisture content of stored products:

Moisture content is among the important parameters measured in food. The moisture content present in food affects its edibility and shelf life. Hence, the moisture content in the foods affects the shelf life property of the food by reducing crispiness of the food.

A petridish was weighed with lid (W1) and approximately 10g of stored sample was weighed into it and weighed again (W2). Petridish along with the stored sample was dried in an oven at 100- 105^{o} C for 15- 17 h and cooled in a desiccator and weight was noted (W3). The same process was repeated till constant weight was obtained.

Calculation:

$$\text{Moisture (\%)} = \frac{(W2 - W1) - (W2 - W3)}{(W2 - W1)} \times 100$$

3.9.2 Evaluation of sensory quality characteristics:

The sensory quality evaluation was conducted with the panel of 10 members consisted of residents of Redhills area, who were mostly from the age 25 -40 years and belong to same locality. The panellists had no knowledge of the project objectives. All the three samples were coded using random three digit numbers.

Panellists were provided with a glass of water and instructed to rinse and swallow water between samples. They were given written instructions and asked to evaluate the products for acceptability based on its colour, appearance, flavour, taste, texture and overall acceptability using 9-point hedonic scale. Appendix- X contains the score card for the sensory evaluation for the shelf life of three selected varieties. (Meilgaard *et.al*., 1999).

3.10 STATISTICAL ANALYSIS

Mean and standard deviation for the three parallel replicates were calculated. Analysis of variance (ANOVA) was used to test the difference between mean, which were analyzed by turkey test at 95% ($p < 0.05$) level of significance using statistical software (Snedecor and Cochran, 1983).

RESULT AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The findings of the present study are discussed and presented under the following sections.

4.1 Puffing of rice varieties

4.2 Sensory Evaluation of the six puffed varieties

4.2.1 Selection of three best puffed varieties

4.3 Physical characteristics of puffed rice

4.3.1 Colour

4.3.2 Texture

4.3.3 Length and diameter

4.3.4 Volume

4.3.5 Mass

4.3.6 Bulk density

4.4 Functional quality characteristics of puffed rice

4.4.1 Volume expansion ratio

4.4.2 Water absorption index

4.5 Nutritional composition of puffed rice

4.5.1 Moisture

4.5.2 Carbohydrate

4.5.3 Protein

4.5.4 Fat

4.5.5 Ash

4.5.6 Dietary fibre

4.6 Resistant Starch of puffed rice

4.7 In- vitro digestibility of puffed rice

4.7.1 In- vitro carbohydrate digestibility

4.7.2 In- vitro protein digestibility

4.8 Shelf life studies of puffed rice

4.8.1 Moisture content of stored samples

4.8.2 Sensory evaluation of stored samples

4.1 PUFFING OF THE RICE VARIETIES:

Puffed rice was prepared using different varieties of rice belonging to Telangana state. There were six varieties of rice that were chosen for the puffing process. The six rice varieties were WGL 44, WGL 283, RNR 2458, MTU 1010, MTU 10001 and 11118. These varieties were puffed and were subjected to sensory evaluation, to choose best three varieties out of the six for further evaluation.

These rice varieties were puffed using a traditional procedure, where the rice was soaked in water for thirty minutes and then pressure dried. The rice was dried to reduce the moisture content of the rice to 10 – 12% and the rice then fried at high temperatures for few seconds in a deep fryer. The heat makes the rice puff and the resultant product was

Fig.1. Pictures of three accepted rice varieties after puffing. This procedure is similar to that of Edmund and Lloys (2002). The resultant puffed rice was packed in Polyethylene Terephthalate (PET) bags to carry out shelf life studies of the three accepted rice varieties over a period of three months.

4.1.2 Packaging:

The puffed rice were dried and were made into portions to pack them. All the three experimental samples were packed in Polyethylene Terephthalate (PET) packets for shelf life studies. The samples were packed and kept at room temperature for three months and the change in their quality was studied.

4.2 SENSORY EVALUATION OF ALL PUFFED VARIETIES:

The six rice varieties that were subjected to traditional puffing were evaluated on their sensory attributes. Ten semi trained judges were asked to taste the six coded puffed rice and score accordingly. The puffed rice were tested on a nine point hedonic scale. The six rice varieties of Telangana state were subjected to sensory evaluation and the best three excepted varieties were chosen for further evaluation, (table. 4.1) shows the sensory evaluation of the six varieties of puffed rice. The appendices- I contains the nine point hedonic scale to measure the sensory qualities of six puffed rice varieties.

The sensory score for colour was shown be higher in WGL44 (8.30) and the lowest value was observed in the variety MTU1010 (7.7) and MTU10001 (7.7). The three best accepted varieties were WGL 44(8.30), WGL 283 (8.20) and RNR 2458 (8.10). There was significance difference (≥0.05%) WGL 44 and MTU 1010, MTU1001, JGL 1118.

The sensory score for appearance was shown to be highest in WGL 44(8.30) and the lowest was observed to be in JGL11118 (7.6). The three best accepted varieties were WGL 44 (8.30), WGL 283 (8.20) and RNR 2458 (8.20). There was significance difference (≥0.05%) between WGL 44 and MTU 1010, MTU1001, JGL 1118 varieties. There was significance difference (≥0.05%) between WGL 283 and MTU 1010, MTU 1001, JGL 1118 varieties.

The sensory score for texture was shown to be highest in WGL44 and RNR 2458 (8.50) and the lowest score was observed in MTU1010 (7.4). The three best accepted varieties were WGL 44 (8.50), RNR 2458 (8.50) and WGL 283 (8.20). There was significance difference (≥0.05%) between the varieties WGL 44, WGL 283, RNR 2458 and MTU 1010, MTU1001, JGL 1118. There was significance difference (≥0.05%) between the varieties WGL 44, WGL 283, RNR 2458 and MTU 1010, MTU1001, JGL 1118. There was no significance difference (≤0.05%) among WGL44, WGL 283 and RNR 2458 varieties.

The sensory score for taste was observed to highest in RNR 2458 (8.50) and lowest score was observed to be in MTU 1010 (7.50). The three best accepted varieties were RNR 2458 (8.50), WGL 44 (8.40) and WGL 44 (8.20). There was significance difference (≥0.05%) between the varieties WGL 44, WGL 283, RNR 2458 and MTU

1010, MTU1001, JGL 1118. But there was no significance difference between WGL 283 and MTU 1001.

The sensory score for flavour was observed to highest in WGL 44 and RNR 2458 (8.30) and the lowest score was observed in MTU 1010 (7.7). The three best accepted varieties were WGL 44 (8.30), RNR 2358 (8.30) and WGL 283 (8.20). There was no significance difference (≤0.05%) among WGL 44, WGL 283, RNR 2458 and MTU 10001.

The sensory score for mouth feel was observed to be highest in WGL 283 (8.30) and the lowest value was observed in MTU 1010 (7.6). The three best accepted varieties were WGL 283 (8.30), RNR 2458 (8.20) and WGL 44 (8.10). There was no significance difference (≤0.05%) among MTU 10001 and JGL 1118. There was no significance difference among WGL 44, WGL 283 and RNR 2458 and also among MTU 1010, MTU 10001 and JGL 1118.

The sensory score for overall acceptability was observed to be highest in varieties like WGL 44, WGL 283 and RNR 2458 (8.20), these were observed to be the three best accepted varieties. The other varieties were shown to have lower scores MTU 1010 (7.4), MTU 10001 (7.5) and JGL 11118 (7.5). The overall acceptability defines the overall quality of the product based on the sensory attributes. There was significance difference (≥0.05%) between the varieties WGL 44, WGL 283, RNR 2458 and MTU 1010, MTU10001, JGL 1118.

Table.4.1. Means of sensory evaluation of six puffed rice varieties.

Varieties	Colour	Appearance	Flavour	Taste	Texture	Mouth feel	Overall acceptability
WGL44	8.30^{a} ± 0.15	8.30^{a} ± 0.15	8.30^{ac} ± 0.15	8.40^{a} ± 0.16	8.50^{a} ± 0.17	8.10^{a} ± 0.10	8.20^{a} ±0.13
WGL283	8.20^{a} ± 0.20	8.20^{a} ± 0.13	8.20^{ac} ± 0.13	8.20^{ac} ± 0.13	8.20^{a} ± 0.13	8.30^{a} ± 0.15	8.20^{a} ± 0.13
RNR2458	8.10^{a} ± 0.23	8.20^{a} ± 0.13	8.30^{ac} ± 0.15	8.50^{a} ± 0.17	8.50^{a} ± 0.17	8.20^{a} ± 0.13	8.20^{a} ± 0.13
MTU1010	7.70^{ab} ± 0.15	7.70^{b} ± 0.15	7.70^{b} ± 0.15	7.50^{b} ± 0. 17	7.40^{b} ± 0.22b	7.60^{b} ± 0.16	7.40^{b} ± 0.16
MTU10001	7.70^{ab} ± 0.15	7.70^{b} ± 0.15	8.00^{bc}± 0.00	7.80^{bc} ± 0.13	7.60^{b} ± 0.16	7.70^{ac}± 0.00	7.50^{b} ± 0.17
JGL11118	7.90^{a} ± 0.10	7.60^{b} ± 0.16	7.80^{b} ± 0.133	7.80^{b} ± 0.13	7.50^{b} ± 0.17	7.60^{bc} ± 0.15	7.50^{b} ± 0.16
Mean	7.98	7.95	8.05	8.03	7.95	7.95	7.85
CD value	0.51	0.44	0.39	0.46	0.50	0.38	0.42
CV% value	7.12	6.19	5.39	6.41	6.99	5.27	5.99

NOTE:

- ± shows mean and standard deviation of triplicate value of each variety
- The supercripts shows the significance difference at ≥0.05.

4.2.1 Selection of Three Best Puffed Varieties

All the six puffed rice varieties were subjected to sensory evaluation and the means of all the scores were calculated. The overall attributes were calculated of all the six rice puffed varieties. The attributes that were tested were colour, appearance, texture, taste, flavour, mouth feel and over all acceptability. The three puffed rice varieties that scored the highest were WGL 44, WGL 283 and RNR 2458. These three best accepted puffed rice varieties were then subjected to physico- chemical, nutritional properties and shelf life studies to select the best variety suitable for puffing. Fig.4.1 shows the best three puffed rice varieties.

4.3 PHYSICAL CHARACTERISTICS OF PUFFED RICE:

The physical characteristics of the puffed rice were estimated for the acceptability of the final product its physical and expansion characteristics play an important role. Most of the puffed snack products are expected to have a puffed structure, which can be measured and quantified by a number of methods such as volume expansion ratio, bulk density and water absorption index. The results of the physical properties are shown in table 4.2.

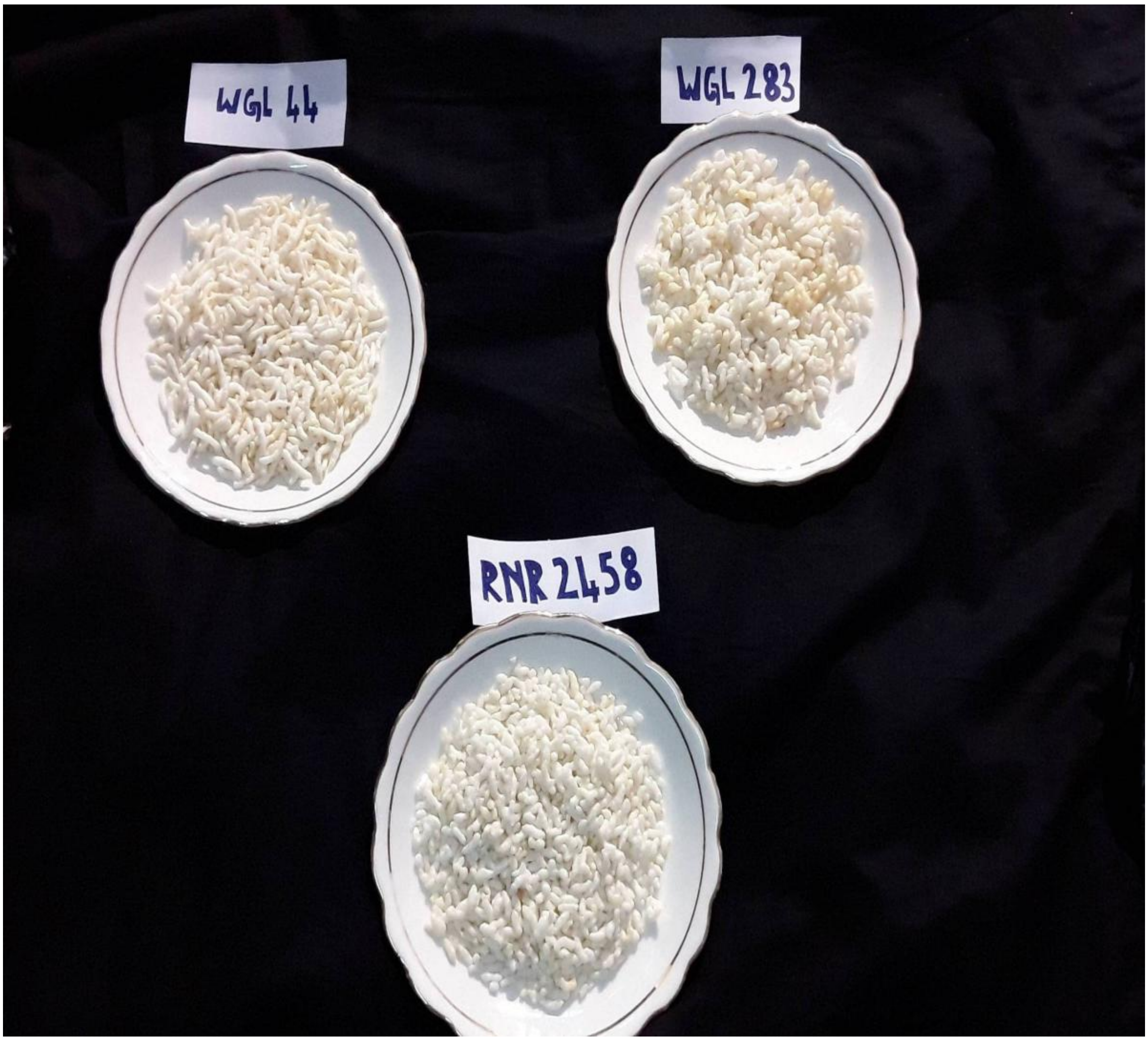

Fig. 4.1. The three best accepted varieties of puffed rice.

4.3.1 Colour:

The L value of WGL 44, WGL 283 and RNR 2458 are 91.26, 85.86 and 89.14 respectively. The a values of WGL 44, WGL 283 and RNR 2458 are 0.11, 4.02 and 1.63 respectively. The b value of WGL 44, WGL 283 and RNR 2458 are 8.12, 10.12 and 9.22 respectively. Fig 4.2 show the colour properties of the three puffed rice varities. There was significane difference (≥0.05%) observed in colour of the three varieties of the puffed rice.

The colour properties are viewed under three parameters, the L (Lightness) value ranging from 85.86 to 91.26, the a (redness) value ranging from 0.11 to 4.02 and the b(yellowness) value ranging from 8.12 to 10.12. The study by Kumar and Prasad (2013) reported the colour parameters of gun puffed rice to be 76.33 as L value, 0.67 as a value and 0.33 as b value. The difference in the techniques and the temperature of puffing has brought in the changes in the colour propertis of the puffed rice.

4.3.2 Texture:

The texture of the puffed rice ranged from 37.92 to 52.18. Table.4.2 shows the texture value of all the three varieties of puffed rice. The textural value was observed to be highest in WGL 283 with 52.18, whereas the lowest value was observed in RNR 2458 with 37.92. The compression force of WGL 44 was 48.41. There was significant difference (≥0.05%) observed among WGL 44, WGL 283 and RNR 2458 varieties of puffed rice.

The compression force of the extruded snacks ranges from 21.6 to 34.2 in a study conducted by Amanda and Ana (2014). The difference in the values could be due the treatments between the two products, as the extrusion process takes place at higher temperature and makes the product more puffed and crispy, when compared to the experimented puffed rice causing change in there puffing properties bringing textural difference in the products.

4.3.3 Length and diameter (mm):

The highest length was observed to be in WGL 44 with 16.73 mm and the lowest length was observed to be in WGL 283 with 10.68 mm, (table 4.2.) shows the length and diameter of all the three varieties of puffed rice. The length of RNR 2458 was 12.14 mm. the diameter of the puffed products ranged from 2.37mm to 3.84mm, where the highest diameter value was observed in WGL 283 and the lowest was observed in WGL

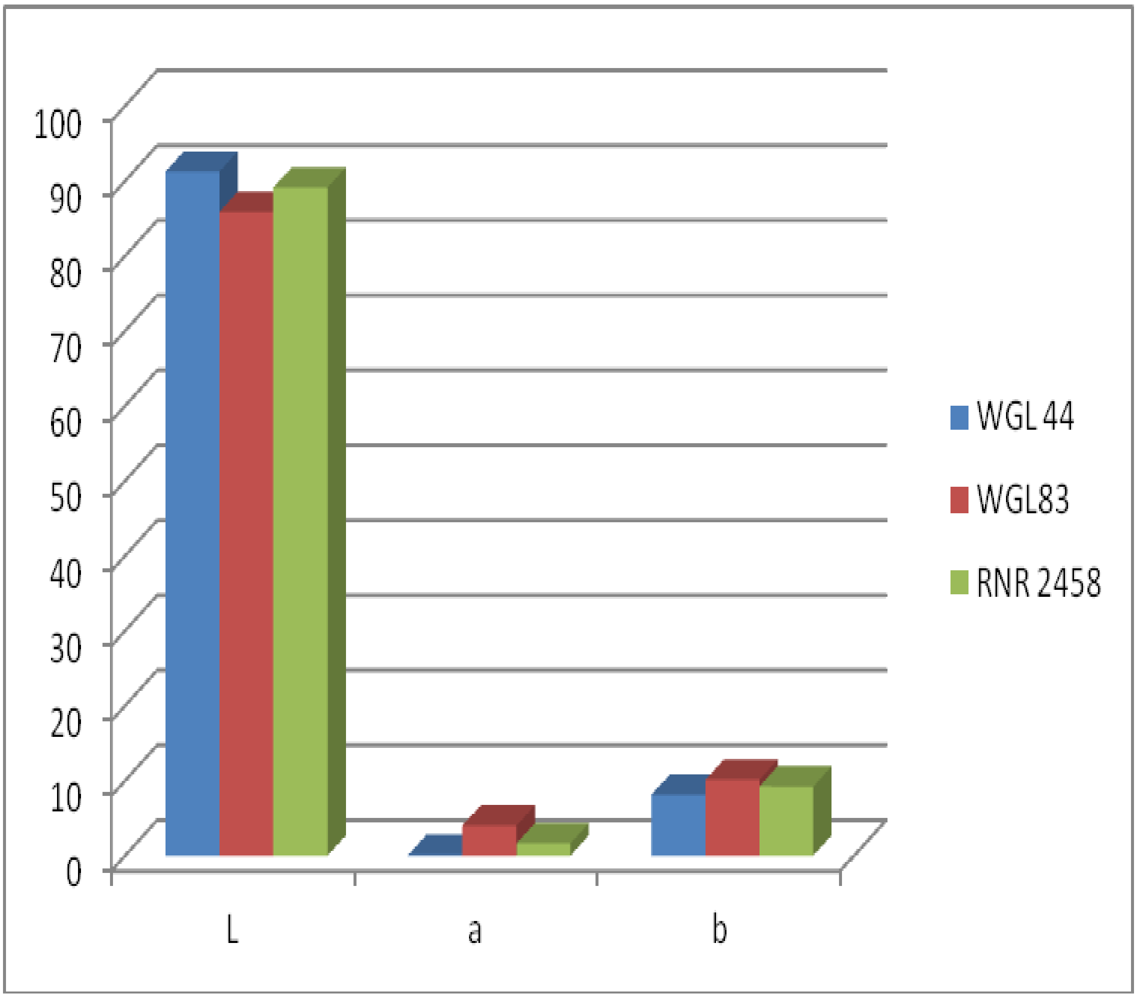

Fig 4.2. Colour properties of the three varities of puffed rice**.**

44. The diameter of RNR 2458 was observed to be 2.81mm. There was significant difference in length (≥0.05), among the three puffed rice varieties. Whereas, the diameter of the three varieties had significant difference between WGL44 and WGL283 while WGL 283 and RNR 2458 showed no significant difference (≥0.05)

The length of the puffed rice ranged from 10.68 mm to 16.73 mm. The diameter of the puffed rice ranged from 2.37 mm to 3.84 mm. similar results were shown in the study done by Kumar and Prasad (2013). According to the study, the length of the puffed rice was observed to be 16.43 mm, whereas the diameter was observed to be 4.74 mm which was observed to be slightly more than the experimental value. The difference in the diameter might be due to the method of puffing, as gun puffing gives better puffing than the traditional method bringing in changes in the puffed rice diameter.

4.3.4 Volume:

The volume of the puffed rice ranged from 17.66 to 25.41cm^3, (table 4.1) shows the volume of all the three selected varieties of puffed rice. The variety WGL 44 showed to have less volume when compared to other two varieties i.e. WGL 283 which has volume of 19.82 cm^3 and RNR 2458 was observed to have highest volume with 25.41 cm^3. The significance difference (≥0.05%) was seen among the volume of the three varieties of puffed rice.

4.3.5 Mass:

The mass of the puffed rice were similar in the three varieties. The mass of the puffed rice of WGL44, WGL283 and RNR2458 was 0.02gms, (table 4.2) shows the mass of the three selected varieties of puffed rice. There was no significant difference (≥0.05%) among all the three varieties of the puffed rice. The mass of all the varieties were observed to be similar in all the varieties.

4.3.6 Bulk density:

The highest bulk density was observed to be in WGL 44 i.e. 0.18 g/cm^3, whereas the lowest bulk density was found to be of WGL 283 with 0.12 g/cm^3. The bulk density of RNR 2458 was found to be 0.15 g/cm$^{3.}$ (Table 4.2) shows the bulk density of all the three varieties of puffed rice. There was significant difference (≥0.05%) in the bulk density of all the three varieties of puffed rice.

The bulk density of the puffed rice varieties ranged from 0.12 to 0.18 g/cm^3. Similar results were reported by Jyothi *et al.* (2009) for starch extrudates, the bulk density ranged from 0.13 to 0.19 gcm^3. Whereas, the bulk density of raw rice kernels were reported by Prashant and Prasad (2012) were 0.80 to 0.90 g/cm^3. The difference in the results of raw and puffed rice may be due to the difference in the puffing techniques the rice undergoes, as gun puffing is a mechanical method of puffing, bringing in changes in the bulk density of the rice.

Table 4.2. Means of length, diameter, texture and volume of the three varieties of puffed rice:

	Length (mm)	Diameter (mm)	Texture (N)	Volume (cm^3)	Mass (g)	Bulk density (g/cm^3)
WGL 44	16.73^a ± 0.10	2.37^b ± 0.48	48.41^b±0.01	17.66^a ± 0.04	0.02^{ac} ± 0.01	0.18^a ± 0.01
WGL 283	10.68^c ±0.05	3.84^a±0.73	52.18^a± 0.07	19.82^b ± 0.03	0.02^{ab} ± 0.01	0.12^c ± 0.01
RNR 2458	12.14^b ± 0.03	2.81^{ab} ± 0.10	37.92^c ± 0.01	25.41^c ± 0.02	0.02^{bc} ± 0.02	0.15^b ± 0.01
Mean	13.19	3.01	46.17	20.96	0.02	0.15
CD	0.17	1.40	0.10	0.07	0.01	0.02
CV % value	0.56	20.49	0.10	0.16	0.01	6.98

NOTE:

- ± shows mean and standard deviation of triplicate value of each variety
- The supercripts shows the significance difference at ≥0.05.

4.4 FUNCTIONAL QUALITY CHARACTERISTICS OF PUFFED RICE

4.4.1 Volume expansion ratio:

The volume expansion ratio of WGL 44, WGL 283 and RNR 2458 were found to be 1.50, 1.39 and 1.26 cm^3 respectively. WGL44 shows the highest expansion ratio and RNR 2458 have the lowest volume expansion ratio. (Table 4.3) shows the volume expansion ratio of the three varieties of puffed rice. There was significant difference (≥0.05%) in the volume expansion ratio of the three varieties of puffed rice.

The volume expansion ratio of the puffed rice ranged from 1.26 to 1.50 cm^3. The results by Suchada and Woatthichai (2010), reported the volume expansion ratio of puffed rice done by microwave puffing to be 2.17 to 2.37 cm^3. In this study, the moisture content and the temperature is directly proportion to the expansion properties. The difference in the results is due to the techniques used to puff the rice and the moisture content, as the temperature and moisture content was higher in microwave puffing than in traditional puffing method.

4.4.2 Water absorption index:

The water absorption index of the three varieties WGL 44, WGL 283 and RNR 2458 are 4.65, 6.66 and 5.83 $g.g^{-1}$ respectively. The highest value was observed in WGL 283 having lowest bulk density and WGL 283 has lowest water absorption index and high bulk density. Table 4.3 shows the details of both parameters of three varieties of puffed rice. There was significant difference (≥0.05%) in the water absorption index of the three varieties of puffed rice.

The water absorption index of the puffed rice for different varieties ranged from 4.65 to 6.66$g.g^{-1}$. Similar results were found in a study by Agnieszka *et.al* (2015), where the water absorption of whole grain wheat puffs was 4.7$g.g^{-1}$. It was observed that water absorption in index was inversely proportional to bulk density.

Table 4.3. Means of volume expansion ratio and water absorption index of three varieties of puffed rice

	Volume expansion ratio (cm^3)	**Water absorption index ($g.g^{-1}$)**
WGL 44	$1.50^{a} \pm 0.01$	$4.65^{c} \pm 0.01$
WGL 283	$1.39^{b} \pm 0.01$	$6.66^{a} \pm 0.01$
RNR 2458	$1.26^{c} \pm 0.01$	$5.83^{b} \pm 0.02$
Mean	1.38	5.71
CD	0.02	0.02
CV % value	0.48	0.18

NOTE:

- ± shows mean and standard deviation of triplicate value of each variety
- The supercripts shows the significance difference at ≥0.05.

4.5 NUTRITIONAL COMPOSITION OF PUFFED RICE:

4.5.1 Moisture:

The moisture content of the three varieties of puffed rice WGL 44, WGL 283 and RNR 2458 are 1.37, 1.15 and 1.18% respectively, (table 4.4) show the moisture content of three puffed rice. There was significant difference (≥0.05%) between the varieties WGL 44 and WGL 283 but there was no significance difference between the varieties WGL 283 and RNR 2458. This is desirable for puffed rice to maintain the crispness of the product. Similar results (0.7 to 2.7g) were reported for extrudates made from sorghum and rice (Lakshmi *et.al.,* 2009).

4.5.2 Carbohydrate:

The carbohydrate content of the three puffed rice varieties WGL 44, WGL 283 and RNR 2458 are 78.57, 76.70 and 75.50g respectively. The highest carbohydrate level was found to be in WGL 44 and the lowest was observed in RNR 2458. Table 4.4 shows the carbohydrate content of the accepted puffed rice varieties. There was significant difference (≥0.05%) between all the three varieties of puffed rice.

4.5.3 protein:

The protein value of the three varieties WGL 44, WGL 283 and RNR 2458 are 6.33, 6.55 and 6.58 g. Table 4.4 shows the protein content of the three accepted varieties of puffed rice. There was no significant difference (≥0.05%) between the varieties WGL 283 and RNR 2458 varieties of puffed rice. Similar results were reported by Hoke *et.al* (2005), the protein content of twelve different rice varieties ranged from 5.04 to 8.40 g. The highest protein content was observed in RNR 2458 and lowest in WGL 44.

4.5.4 Fat:

The fat content of the three puffed rice varieties ranged from 0.92 to 0.95g. Table 4.4 shows the fat content of the selected three varieties of puffed rice. The highest fat content was found to be in WGL 44 and the lowest content in RNR 2458. The fat content of WGL 283 was 0.94g. There was no significant difference (≥0.05%) between the varieties WGL 283 and RNR 2458.

4.5.5 Ash content:

The ash content of the rice varieties ranged from 0.23 to 0.73%. The highest ash content was observed in WGL283 and the lowest was observed in WGL 44. The ash content of RNR 2458 was 0.42 %. Table 4.4 shows proximate analysis of the three varieties of puffed rice. There was significant difference (≥0.05%) among all the three varieties of puffed rice.

Table 4.4 Means of moisture, carbohydrate, protein, fat and ash of the three rice varieties of Telangana state.

	Moisture (%)	Carbohydrate (g)	Protein (g)	Fat (g)	Ash (%)
WGL 44	1.37^{a} ± 0.01	78.57^{a} ± 0.06	6.33^{c} ± 0.05	0.95^{a} ± 0.02	0.23^{c} ± 0.02
WGL 283	1.15^{b} ± 0.01	76.70^{b} ± 0.10	6.55^{ab} ± 0.01	0.94^{ab} ± 0.02	0.73^{a} ± 0.02
RNR 2458	1.18^{bc} ± 0.02	75.50^{c} ± 0.10	6.58^{a} ± 0.02	0.92^{b} ± 0.02	0.42^{b} ± 0.02
Mean	1.23	76.92	6.49	0.94	0.46
CD	0.03	0.07	0.06	0.02	0.02
CV % value	1.08	0.04	0.43	1.12	2.30

NOTE:

- ± shows mean and standard deviation of triplicate value of each variety
- The supercripts shows the significance difference at ≥0.05.

4.5.6 Dietary fibre:

The dietary fibre of the three different puffed rice varieties of Telangana state WGL 44, WGL 283 and RNR 2458 ranged from 0.88 to 0.92 mg. The highest dietary fibre was observed in WGL 44 and the lowest in RNR 2458. The dietary fibre in WGL 283 was 0.91 mg. Table 4.5 shows the dietary fibre content of the three puffed rice varieties. There was no significant difference (≥0.05%) between the three varieties of the puffed varieties in their dietary fibre. Slightly more amount of dietary fibre was reported by Gajula *et.al* (2008) where the dietary fiber was 1.5 to 2.5 % in bran flour extrudates.

Table 4.5. **Dietary fibre of the three varieties of puffed rice.**

	Dietary fibre (g)
WGL 44	$0.92^{ac} \pm 0.02$
WGL 283	$0.91^{ab} \pm 0.01$
RNR 2458	$0.88^{bc} \pm 0.02$
Mean	0.91
CD	0.04
CV % value	2.05

NOTE:

- ± shows mean and standard deviation of triplicate value of each variety
- The supercripts shows the significance difference at ≥0.05.

4.6 RESISTANT STARCH OF PUFFED RICE:

The resistant starh content of the rice varieties WGL 44, WGL 283 and RNR 2458 are 2.29, 2.23 and 2.27 g respectively. Table 4.6 shows the resistant starch content of the three vareties of puffed rice. The highest amount of resistant starch was observed in WGL 44 and the lowest amount obsereved in WGL 283. There was no significance difference (≥0.05%) between WGL 44 and WGL 283. But there is no significance difference (≥0.05%) between WGL 283 and RNR 2458. Similar results were reported by Ruchi and Sheth (2011), the resistant starch of cereal based puffed products ranged from 0.53 g to 2.09 g.

Table 4.6 Resistant starch content in three varieties of puffed rice.

	Resistant starch (g)
WGL 44	2.29^{ac} ± 0.01
WGL 283	2.23^{bc} ± 0.02
RNR 2458	2.27^{a} ± 0.01
Mean	2.26
CD	0.02
CV % value	0.39

NOTE:

- ± shows mean and standard deviation of triplicate value of each variety
- The supercripts shows the significance difference at ≥0.05.

4.7 IN- VITRO DIGESTIBILITY OF PUFFED RICE:

4.7.1 In- vitro carbohydrate digestibility

The in vitro carbohydrate digestibilty of the three rice varieties WGL 44, WGL 283 and RNR 2458 ranges from 80.28 to 82.21%. The highest digestibilty of carohydrate was observed in RNR 2458 and the lowest digestibilty was observed in WGL 283. Fig. 4.3 shows the invitro carbohydrate digestibilty of the three varieties of puffed rice. The in vitro carbohydrate digestibilty in WGL 44 was 81.31 %. There was significant difference (≥0.05%) in the in vitro carbohydrate value between the three varieties of puffed rice.

4.7.2 In- vitro protein digestibility

The in vitro protein digestibility of the three rice varieties of Telangana state WGL 44, WGL 283 and RNR 2458 are 86.30, 83.60 and 82.67% respectively. The in vitro digestibilty of protein was observed to be higher in WGL 44 and lowest in RNR 2458. The invitro digestibilty means of the three varieties are shown in the Fig 4.4. There was significant difference (≥0.05%) in the in vitro protein digestibility value between the three varieties of puffed rice. Lower protein digestibilty was reported in wheat based extrudate products ranging from 59.26 to 65.61 % (Swapnil *et.al.*, 2016). The difference in the results might be due to the difference in the content of wheat and rice and also their digestibility after processing.

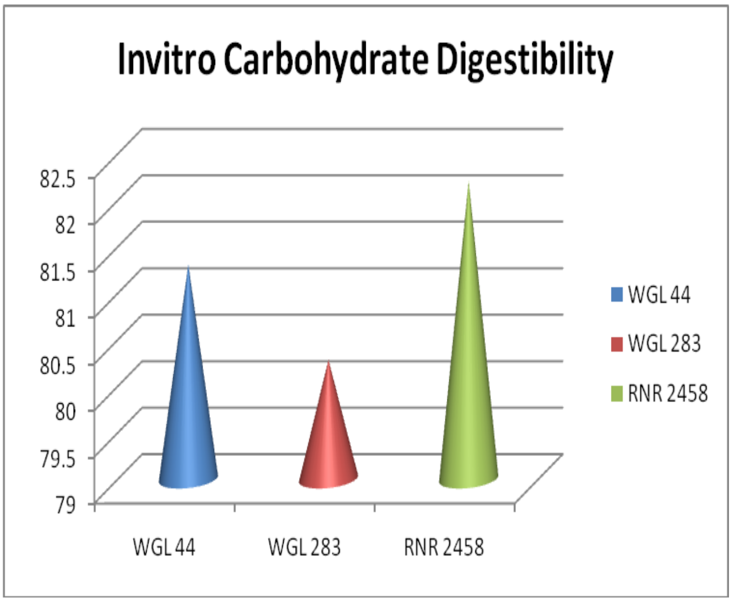

Fig. 4.3 Invitro carbohydrate digestibility of the three varieties of puffed rice

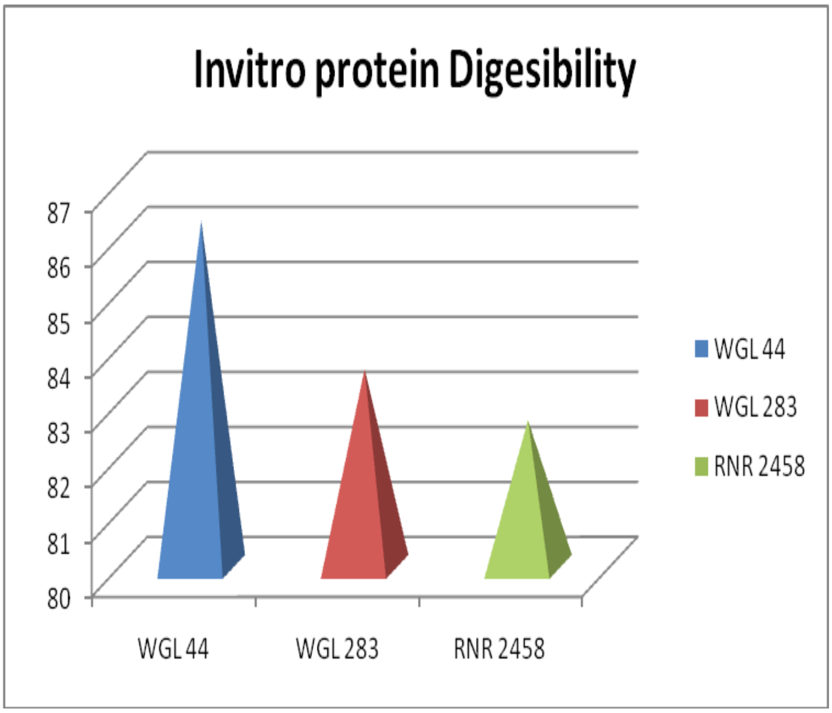

Fig. 4.4 Invitro protein digestibiliy of the three varieties of puffed rice

4.5 SHELF LIFE OF THE STORED SAMPLE:

4.5.1 Moisture content of the stored sample:

The storage stability of the puffed rice was evaluated by two parameters i.e. moisture content and sensory evaluation. Developed products were packed in PETand stored at room temperature for a period of three months. The figure 4.5 shows the moisture content of the three puffed rice on 0 day and 90th day. The moisture content of the samples was estimated before and after the storage period of three months. There was observed to be significant difference (≥0.05%) in the moisture content of the three varieties of puffed rice.

The change in the moisture content increased during storage of three months. The increase in the moisture content can bring in changes in the textural and acceptibility of the puffed rice.

4.5.2 Sensory evaluation of stored samples:

Sensory evaluation was done on the three rice varieties before and after the storage period. There were changes in the products. The sensory evaluation was done by a panel of semi trained judges on a nine point hedonic scale. fig 4.6, 4.7 and fig.4.8 shows the sensory results of the three rice varieties of WGL44, WGL283 and RNR2458 respectively.

The sensory evaluation for the colour was observed to decrease slightly for all the three varieties. The score for WGL 44 decreased from 8.30 to 8.00. the score for WGL 283 also decreaced frm 8.20 to 7.80. the RNR 2458 variety also showed a decreased colour score from 8.10 to 7.80. There was no significance differenace (≤0.05%) among the three puffed rice varieties.

The sensory score for appearance did not show much difference for all the three varieties. The score for WGL 44 changed from 8.30 to 8.10. The score for WGL283 changed from 8.20 to 8.10 and for RNR 2458 the score varied from 8.20 to 8.10. There was no significance differenace (≤0.05%) among the three puffed rice varieties.

The sensory evaluation for the flavour was observed to decrease slightly for all the three varieties. The score for WGL 44 decreased from 8.30to 7.50. the score for WGL 283 also decreaced frm 8.20 to 7.40. the RNR 2458 variety also showed a decreased colour score from 8.30 to 7.40. There was no significance differenace (≤0.05%) among the three puffed rice varieties.

The sensory score for taste did not show much difference for all the three varieties. The score for WGL 44 changed from 8.40 to 8.20 that for WGL283 changed from 8.20 to 8.10 and for RNR 2458 the score changed from 8.50 to 7.90. At the end of the storage period there was no significant differenace (≤0.05%) among the three puffed rice varieties.

The sensory score for texture and mouthfeel was observed to register higher difference. During storage the texture and mouthfeel score for WGL 44 decreased from 8.50 to 6.80 and 8.10 to 6.60 respectively. The texture and mouthfeel score for WGL 283 reduced from 8.20 to 7.20 and 8.30 to 6.60 respectively. the score for RNR 2458 texture and mouthfeel also reduced from 8.50 to 6.90 and 8.20 to 6.70 repectivey. These two parameters are greatly effected by the moisture content of the rice varieties that increased during the storage period. In a study by Dong et.al (1990) the shelf life study of puffed rice showed low score in overall acceptibility of the product, whereas the texture and flavour did not show much change in the score.

The scores for overall acceptibilty of the products were reduced over the period of the storage due to the change in the flavour, texture and mouthfeel of the puffed samples. The scores for overall acceptibility for all the varieties i.e. WGL 44, WGL 283 and RNR 2458 reduced from 8.20 to 7.00. There was no significant differenace (≤0.05%) among the three puffed rice varieties.

Fig 4.6. Moisture content at day 0 and day 90.

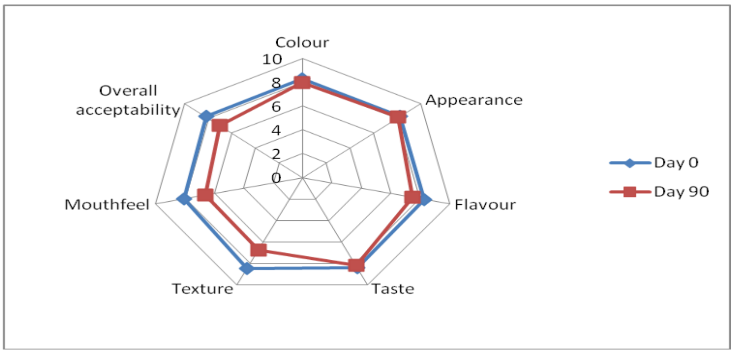

Fig 4.7. Sensory evaluation of WGL 44

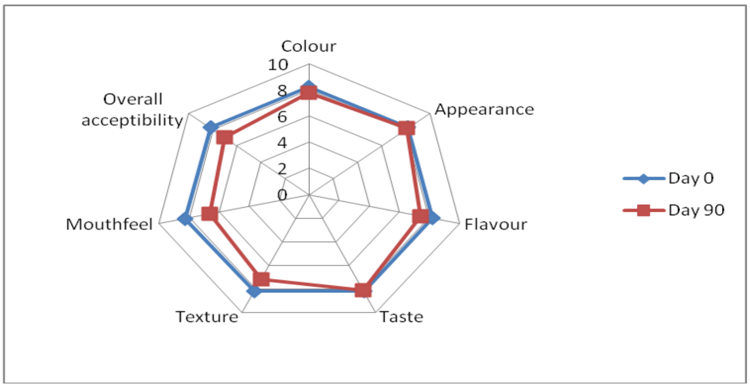

Fig. 4.8. Sensory evaluation of WGL283

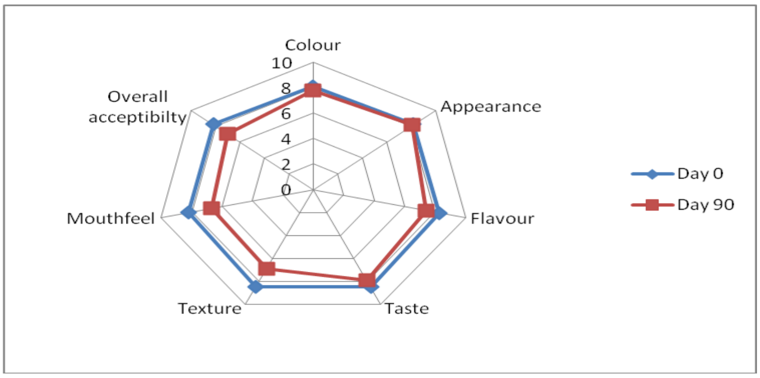

Fig. 4.9. Sensory evaluation of RNR 2458.

SUMMARY AND CONCLUSION

CHAPTER- V

SUMMARY AND CONCLUSION

Rice is the largest commodity to the people as it is a part of our daily lifestyle. It contributes to be a major source for carbohydrate to the individual by supplying 60 percent of dietary intake. Among the many states in India, Telangana state has contributed largely to supply of rice to the country. A variety of rice products are produced in order to enhance the storage capability, easy cooking to instant cooking and provide new food with better nutritive value and flavour.

One such technique is puffing of rice, which became base for many other convenient foods in the market. Usually puffed rice is made from sundried paddy which was moistened in hot water for some time. In the traditional method of puffing, the rice is soaked in water and then steamed later for 10 min. The cooked rice is dried in to 12-15% moisture and fried in oil at 220^{o} C for 4-8 sec in a deep fryer. The puffed rice are then packed to get transported and also increase the shelf life of the product.

Six varieties of Telangana state JGL 11118, MTU 1010, MTU 1001, RNR 2458, WGL 44 AND WGL2 83 were subjected to puffing and then evaluated for sensory properties based on the nine point hedonic scale. The varieties RNR 2458, WGL 44 and WGL 283 scored highest on overall acceptability of the product. The score for overall acceptability for all the three varieties were 8.20 on the scale. These accepted varieties were then subjected to physico- chemical analysis, nutritional analysis and shelf life studies.

The physico chemical analysis was carried out on the three accepted varieties. The length of WGL 44, WGL 283 and RNR 2458 were 16.73mm, 10.68mm and 12.14mm respectively. The diameter of WGL 44 was 3.84mm, WGL 283 was 2.37mm and RNR 2458 was 2.81mm. The texture of the puffed rice varieties WGL 44, WGL 283 and RNR 2458 are 48.41, 52.18 and 37.92 respectively. The volume of the puffed rice varieties WGL 44 was 17.66 cm^3, WGL 283 was 19.82 cm^3 and RNR 2458 was 25.41 cm^3. The mass of the puffed rice varieties WGL 44, WGL 283 and RNR 2458 were found to be 0.02g for all the varieties.

The physical parameters that measure the puffing properties were done on the three selected varieties. The Bulk density of the three varieties WGL 44, WGL 283 and RNR

2458 were found to be 0.18, 0.12 and 0.15g/cm^3 respectively. The Volume expansion ration of the varieties WGL 44 was 1.50cm^3, WGL283 was 1.39cm^3 and RNR 2458 was 1.26cm^3. The Water absorption index shown highest result in WGL 283 with 6.66g.g^{-1} and lowest score observed in WGL44 with 4.65g.g^{-1}. The RNR 2458 variety's water absorption index was 5.83g.g^{-1}. The puffed rice variety WGL 283 showed better results in physical parameters.

The colour intensity was also measured for all the three puffed rice varieties. The level of whiteness (L value) of WGL 44 was 91.26, WGL 283 was 85.86 and RNR 2458 was 89.14 of the three puffed rice varieties. The redness (a value) and yellowness (b value) of the varieties WGL 44 was 0.11 and 8.12, WGL 283 4.02 and 10.12 and RNR 2458 was 1.63 and 9.22 respectively.

The three selected puffed rice varieties were subjected to proximate analysis. The moisture content of the varieties WGL 44 was 1.37%, WGL 283 was 1.15% and RNR 2458 was 1.18%. The carbohydrate and protein content of WGL44, WGL283 and RNR 2458 were 78.57g and 6.33g, 76.70 and 6.55g and 70.50 and 6.58g respectively. The fat content of the variety WGL 44 was, WGL 283 was and RNR 2485 were 0.95, 0.94 and 0.92g. The ash content of the varieties WGL 44, WGL 283 and RNR 2458 were 0.23, 0.73 and 0.42% respectively. The puffed rice variety that showed better results on average of the proximate analysis was WGL 44.

The three selected puffed rice varieties were then subjected to in vitro digestibility test to observe the in vitro protein and carbohydrate digestibility. The in vitro carbohydrate digestibility of varieties WGL 44, WGL 283 and RNR 2458 were 81.31, 80.28 and 82.21% respectively. Then these three varieties were tested for in vitro protein digestibility, the digestibility of WGL 44 was 86.30%, the variety WGL 283 was 83.60% and RNR 2458 was 82.67%. The variety that has shown to has the highest level of digestibility on an average was WGL 283.

The results of the shelf life study were evaluated by using the parameters moisture and sensory evaluation by the nine point hedonic scale. The moisture content of the three puffed rice varieties WGL 44, WGL 283 and RNR 2458 were 3.51, 3.14 and 3.89% at the after the shelf life period of three months. The puffed rice varieties were then subjected to sensory evaluation, the overall acceptability score of the variety WGL 44 was 8.20. Similarly the varieties WGL 283 and RNR 2458 were 8.20. The shelf life studies of the three varieties over the period of three months, it was observed that WGL283 showed better results.

Different parameters were examined of the three selected puffed rice varieties. Based on the results obtained, the variety that was observed to be better suited for puffing based on the average of the results was WGL 283. The variety WGL 283 showed the best result in the puffing characteristics. In terms of the proximate analysis and nutritional analysis WGL 44 was slightly more than WGL 283. The average of all the results showed WGL 283 to have better results for puffing.

Future study prospectus:

- A study can be conducted to learn the difference in the puffing characteristics of the varieties by using gun puffing method and microwave method. Find the best method to be used for better puffing properties.
- A study can be conducted to understand the changes in the nutritional parameters by using different puffing techniques.
- A study can be conducted, where the puffed rice can be fortified with minerals like iron to enhance the nutritive quality of the product.

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APPENDICES

APPENDIX- I

SCORE CARD FOR SENSORY EVALUATION OF PUFFED RICE

Name of the product: Puffed Rice **Date:**

Name of the judge:

Instructions:

You are provided with 6 samples of puffed rice, please evaluate the samples for their colour, appearance, texture, taste, flavour, mouth feel and overall acceptability using 9-point hedonic scale. Rate the samples accordingly. Drink water after tasting each sample.

Sensory attributes	s	a	m	P	l	es
	111	654	254	875	786	943
colour						
appearance						
texture						
taste						
flavour						
Mouth feel						
Overall acceptability						

Description:

Like extremely –9, Like very much -8, Like moderately -7, Like slightly -6, Neither like nor dislike -5, Dislike slightly- 4, dislike moderately- 3, dislike very much -2, dislike extremely-1

Comments:

Signature of the judge

APPENDIX- II

ESTIMATION OF TOTAL CARBOHYDRATE

Material used:

- Standard glucose:

  Weigh 25mg of glucose into a 25mlvolumetric flask and make up litre volume with distilled water (1mg/ml)

  Working standard- dilute 5ml of stock glucose solution to 50ml with distilled water (100ml/g)

- Phenol (5%):

  Dissolve 5gm of redistilled (reagent grade) phenol in water and make up to 100ml.

- Sulphuric acid 96% reagent grade

PROCEDURE:

- Hydrolysis of the sample: weigh 50mg of the sample in to tubes. Add 5ml of 2.5 N HCl and hydrolysis by keeping in a boiling water bath for 3hr.99999
- Then cool to room temperature and neutralise with solid Na_2CO_3 until the effeverance ceases. Makeup the volume to 100ml, centrifuge and collect the supernatant for total carbohydrate analysis.
- Pipette out 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard into a series of test tube.
- Pipette out 0.2ml of the sample solution in two separate test tubes.
- Make up the volume in each test tube to 1ml with water.
- Set a blank with 1ml of the water.
- Add 1ml of phenol solution to each tube. Add 5ml of 96% H_2SO_4 to each test tube and shale well.
- Shake the content in the tube and place in a water bath at 25- 30^{o} C for 20 min. And read the value at 490nm.

APPENDIX- III

ESTIMATION OF PROTEIN

The protein content of the whole and processed sample was determined, using the method of AOAC (2005).

The amino nitrogen in various nitrogenous compounds in biological samples get converted in to organo nitrogen in Leco analyzer by combustion of sample through Doumas method, there by protein content is arrived.

EQUIPEMENTS**:** Leco protein analyser and weighing balance

REAGENTS**:** ETDA (Ethylene Tetra Diamine)

PROCEDURE:

1. Set the pressure of helium gas and dry air cylinders at 2.7 bars.
2. Set optimum conditions for the air compressions i.e. 2.7 bar.
3. Switch on the software and main instrument, put on the gases on and place I standby mode.
4. Let the Leco protein analyzer warm up for one to two hours.
5. Go to diagnostics option, select ambient monitor, see for the system parameters as follows and should be in the range limit as detailed.
6. When the instrument is ready, create a method for purging, burning and filling the ballast for combustion of the sample.
7. Enter blank weight by default as 0.500 and press analyze button. Automatically protein percent will be displayed.
8. Repeat blanks until the instrument is stabilized. Blank correction can be done.
9. Analyze standard ETDA (Ethylene Tetra Diamine) four to five times; standard corrected value range is 9.40 to 9.70% of nitrogen. Standards should be calibrated when standard corrected value falls within range.
10. Analyze samples in triplicate and note the average protein in g percent.

APPENDIX- IV

ESTIMATION OF FAT

The fat content of the whole and processed samples processed was determined, using the method of AOAC (1981). Fat is extracted as crude ether extract of the dry material.

CHEMICALS**:** Petroleum Ether

EQUIPEMENTS: Weighing Balance and Soxtherm instrument

PROCEDURE:

1. Clean the extraction beaker.
2. Put a few boiled stones in and let it dry for about an hour at $103^{o} \pm 2^{o}C$ in the drying chamber.
3. Then cool off in the desiccator at room temperature. Weigh the empty beaker (W1) over.
4. Weigh dry sample 5 gm in to thimble.
5. Insert the thimble and put them in the beaker.
6. Add the correct amount of solvent around 150 ml (Petroleum Ether).
7. Put the extract beaker in to the Soxtherm instrument.
8. Check whether the beaker is fitting correctly by slightly turning the beaker so that the sealing rings of the PTFE cylinders fit tightly.
9. Sample is extracted with Petroleum Ether (60- 80^{o} C BP) for about 1 ½ hour.
10. The Ether extract is filtered in to a weighed beaker.
11. Remove petroleum ether by evaporation and dry the residue in an oven at 80- 100^{o} C, cool in desiccators and weigh the Ether extract (w2).

CALCULATIONS:

$$\text{Fat content (g \%)} = \frac{W1 - W3}{\text{Wt of the sample}} \times 100$$

APPENDIX- V

ESTIMATION OF ASH CONTENT

Foods and food products are heated to temperatures of 500 – 600^o C, where the water and other volatile constituents evolve as vapours and the organic constituents were buried in the presence of oxygen to carbon dioxide and oxides of nitrogen and eliminated together with hydrogen as water. The mineral constituents remain in the residue as oxides, sulphates, phosphates and chlorides. The inorganic residue constitutes the ash of food products. The ash content of the sample was determined by using the method of AOAC (2005).

PROCEDURE:

1. The temperatures of the muffle furnace were set to 600^o C and empty crucibles were heated for 1 hour and then cooled in a desiccator and weighed (W_1).
2. 2g of defatted sample was weighed into the crucible and weight was noted (W_2).
3. The sample was kept on flame for charring and then incinerated at 600^o C for 8 hours in muffle furnace.
4. After sample was completely turned to ash, crucibles were transferred into the desiccators, cooled and weighed (W_3).
5. Incineration was repeated until constant weight was obtained.

CALCULATIONS:

Weight of the sample taken = $W_2 – W_1$

Weight of the ash = $W_3 – W_1$

$$\text{Ash content in \%} = \frac{\text{Weight of the ash}}{\text{Weight of the sample taken}} \times 100 = \frac{W_2 - W_1}{W_3 - W_1} \times 100$$

APPENDIX- VI

ESTIMATION OF DIETARY FIBRE

Reagents:

- Sodium Phosphate Buffer (pH 6.0)
- 4 M Hydrochloric Acid solution
- 4 M Sodium Hydroxide solution
- 95 % ethanol
- 78 % ethanol
- Acetone
- Celite.

Enzymes:

- Pepsin
- Pancreatin
- Termamyl (α- Amylase heat stable)

PROCEDURE:

- 1 gm sample was weighed into an Erlemmeyer Flask (500ml) and 25 ml of 0.1 M Sodium Phosphate buffer (pH 6.0) was added and suspended thoroughly.
- 100 ml termamyl was added and top of the flask was covered with aluminium foil and incubated in boiling water bath for 15 mins. (with occasional shaking).
- Contents of the flask were cooled. 20ml of distilled water was added and pH was to 1.5 with HCl. Electrode was rinsed with few ml of water.

- 100 mg pepsin was added; top of the flask was covered and incubated in a water bath a 40^o C with agitation for 60 mins.

- 20 ml of distilled water was added and pH was adjusted to 6.8 with NaOH. Electrode was rinsed with few ml of water.

- 100 mg Pancreatin was added, top of the flask was covered and incubated in a water bath 40^o C with agitation for 60 mins.

- pH was adjusted to 4.5 with HCl.

- After adjusting the pH 4.5 with HCl, soluble dietary fibre precipitated directly by adding 400 ml of warm (60^o C) 95% ethanol to the whole digest after above step and it was allowed to precipitate for 1 hour.

- After precipitation, whole digest was filtered through a dry and weighed crucible containing 0.5 g of celite as filter aid.

- Then the residue was washed with 2 * 10 ml distilled water.2* 10 ml 78% ethanol and 2*10 ml of acetone.

- Dried at 10^o C overnight weighed after coating in a dessicator (D_2).

- Incinerated at 550^o C for at least 5 hours weighed after cooling in a dessicator (I_2).

Blank: A blank was also run simultaneously for total dietary fibre. The blank value should be checked occasionally when new batches of enzymes are used.

CALCULATIONS:

Total dietary fibre

D_2 – weight of the crucible after drying

I_2- weight of crucible after incineration

B_2- TDF blank

W – Weight of the sample (g)

$$\text{Total dietary fibre} = \frac{D_2 - I_2 - B_2}{W} \times 100$$

APPENDIX- VII

ESTIMATION OF RESISTANT STARCH

The estimation of resistant starch present in the puffed rice was determined using AOAC, 2002 method.

REAGENTS REQUIRED: Pancreatin, Ethanol (99%), Amyloglucidase, GOPOD (Glucose Kit), sodium acetate buffer, Sodium Malate, 2M Potassium Hydroxide

PROCEDURE:

1. Accurately weigh a 5mg powdered sample directly into each screw cap tube and gently tap the tube to ensure that the sample falls down at the bottom.

2. Add 4.0mL of pancreatic- α amylase (10mg/ml) containing Amyloglucosidase (AMG) (3U/ml) to each tube.

3. Tightly cap the tubes, mix them on a vortex mixer and attach them horizontally in a shaking water bath, aligned in direction of motion.

4. Incubate tubes at 37^{o} C with continuous shaking for exactly 16h.

5. Remove the tubes from water bath and remove excess surface water with paper towel. Remove the tube caps and treat the content with 4.0 mL of ethanol (99% v/v) with vigorous stirring on vortex mixers.

6. Centrifuge the tubes at 1,500g (approx. 3,000 rpm) for 10 minutes.

7. Carefully decant the supernatants and re- suspend the pallets in 2ml of 50% of ethanol or 50% IMS with vigorous stirring on a mixer. Add a further 6ml of 50% IMS, mix the tubes and centrifuge again 1,500g for 10 min.

8. Decant the supernatants ad repeat this suspension and centrifugation step once more.

9. Carefully decant the supernatant and invert the tubes on absorbent paper to drain excess liquid.

Measurement of Resistant Starch:

1. Add magnetic stirrer and 2ml of 2M KOH to each tube and re suspend the pallets by stirring for approx. 20 min in ice/ water bath over magnetic stirrer.

2. Add 8ml of 1.2M Sodium acetate buffer (pH 3.8) to each tube with stirring on magnetic stirrer. Immediately add 0.1 mL of AMG, mix and place the tubes in a water bath at 50^{o} C.

3. Incubate the tubes for 30 min. with intermittent mixing on a vortex.

4. **For samples > 10 %RS**: quantitatively transfer the contents of the tube to a 10 mL volumetric flask (using a water wash bottle). Use an external magnet to retain the stirrer bar in the tube while washing the solution from the tube with the water wash bottle. Adjust to 100 mL with distilled water and mix well. Centrifuge an aliquot of the solution at 1,500g for 10 mins.

5. **For samples containing < 10% RS:** directly centrifuge the tubes at 1,500g for 10 mins. (no dilution)**.** For such samples, the final volume in the tube is approx. 10.3 mL

6. Transfer 0.1 mL aliquots of either the diluted or undiluted supernatants into the glass test tubes, add 3.0 mL of GOPOD reagent and incubate at 50o C for 20 mins.

7. Measure the absorbance of each solution at 510nm against reagent blank.

CALCULATIONS:

RS (g/100ml) (sample containing > 10% RS):

$= \Delta E * F/W * 90$

RS (g/100ml) (sample containing <10% RS):

$= \Delta E * F/W * 9.27$

Where, ΔE= absorbance read against reagent blank

F= conversion from absorbance to µg

W= dry weight of sample analysed.

APPENDIX- VIII

ESTIMATION OF IN VITRO CARBOHYDRATE DIGESTIBILITY

The ability of the sample to inhibit alpha- amylase activity was determined.

REAGENTS:

0.2 M phosphate buffer:

A = 0.2 M $Na_2HPO_4.2H_2O$,

B= 0.2 M $NaH_2PO_4.2H_2O$.

45ml A and 55ml of B were diluted to 200ml and pH adjusted to 6.9.

3-5 dintro salicylic acid (DNSA) reagents:

2g of DNSA was dissolved in 40ml of water. A solution of 3.2g of sodium hydroxide in 30ml of water was added drop wise with stirring and gently heated on water bath until clear solution was obtained.

60g of potassium sodium tartarate was added in small portions and water added to the final volume of 200ml. the tartarate was added in small portions and water added to the final volume of 200ml. the reagents were stored in dark.

Enzyme buffer:

20mg of pancreatic amylase was dissolved in 50ml of the phosphate buffer and filtered through No. 41 filter paper.

Standard maltose:

100 mg of maltose was dissolved in 100ml of water.

Procedure:

1. Various concentration (10, 20, 40,60, 80 and 100 µg/ ml) of the samples were dispersed in 1.0 ml of 2.0 M phosphate buffer (pH 6.9). 0.5 ml of enzyme buffer was added to the sample suspension and incubated at 37^{o} C for 2 hours.
2. After the incubation period, 2ml of DNSA reagent was quickly added and the mixture was heated for 5min in boiling water bath. After cooling, the solution was made to 25ml with distilled water and filtered.

3. The absorbance was measured at 550nm. A blank was run simultaneously.
4. 4ml of maltose standard was taken and the reaction was started by 3- 5 DNSA reagent. The values were expressed as mg of lactose released /g of sample.

$$\% \text{ inhibition} = \frac{\text{(Enzyme activity of control – enzyme activity of sample)}}{\text{Enzyme activity of control}}$$

The anti- diabetic activity was also expressed as $IC_{50.}$ All the tests were performed in triplicates and the graph was plotted with the average of the three observations.

APPENDIX- IX

ESTIMATION OF IN VITRO PROTEIN DIGESTIBILITY

The digestibility of puffed rice was determined by the method (Aboubacar et.al. 2001).

REAGENTS:

1. Pepsin solution: 20 mg of pepsin was dissolved in 50 l of 40% HCl solution,
2. Pancreatin solution: 50mg of Pancreatin was dissolved in 100 ml of 0.1 M borate buffer (pH 6.8) containing 0.025M calcium chloride.
3. Toluene.
4. 10% (w/v) trichloroacetic acid
5. 5% (w/v) trichloroacetic acid

PROCEDURE:

An amount of sample containing 6.75 $\pm$ 0.1 nitrogen was placed in a 50 ml conical flask and 5ml of pepsin solution was added to flask and incubated in a water bath for 16 hours at 37^{o} C. then 2ml of Pancreatin solution was added and the content were further incubated for 24 hours at 37^{o} C, 2 to 3 drops of toluene was added during incubation and samples were stirred slowly on a mechanical shaker. After 24 hours, the reaction was stopped by adding 20 ml of 10% TCA and the suspension was centrifuged. The residue was washed twice with 5ml of 5% TCA and pooled suspension were up to 25ml with 5% TCA. An aliquot of 5ml was taken and evaporated to dryness at low temperature (80- 90^{o} C) and nitrogen content was determined by the micro Kjeldhal procedure.

Then digestibility of each sample was calculated in the following way

$$IVPD = \frac{\text{Nin the sample supernants} - \text{Nin blank}}{\text{Nin starting material}} \times 100$$

APPENDIX- X

SCORE CARD FOR SENSORY EVALUATION FOR SHELF LIFE STUDIES

Name of the product: Puffed Rice **Date:**

Name of the judge:

Instructions:

You are provided with 6 samples of puffed rice, please evaluate the samples for their colour, appearance, texture, taste, flavour, mouth feel and overall acceptability using 9-point hedonic scale. Rate the samples accordingly. Drink water after tasting each sample.

Sensory attributes	SA	MP	PLES
	546	897	123
colour			
appearance			
texture			
taste			
flavour			
Mouth feel			
Overall acceptability			

Description:

Like extremely –9, Like very much -8, Like moderately -7, Like slightly -6, Neither like nor dislike -5, Dislike slightly- 4, dislike moderately- 3, dislike very much -2, dislike extremely-1

Comments:

Signature of the judge