Introduction
A global interest in rice and its fermented product is increasing due to their calorigenic value, unique quality characteristics and high acceptability. The Nepali people of the Himalayan regions of India, Nepal, and Bhutan prepare a fermented rice based cereal food called sel-roti. Sel-roti is a delicious, deep-fat fried, puffed, ring shaped spongy doughnut like Nepalese indigenous food prepared from the batter of rice flour, ghee and sugar. Sel-roti is consumed in religious festivals and special occasions (Yonzan and Tamang, 2010).

Nepal is a country of ethnical, cultural, religious and linguistic diversity. Therefore, diverse kinds of traditional foods can be found in Nepal, which the people have inherited from their ancestors. Sel-roti is a local Nepali name given to the ring shaped spongy doughnut like Nepalese indigenous food prepared from the batter of rice flour, ghee and sugar. Sel-roti is consumed in religious festivals and special occasions (Yonzan and Tamang, 2010).

Materials and Methods
Old (Kanchhi mansuli) rice, ghee (Sujal Dairy Private Limited, Pokhara) and frying oil (Cello brand refined Sunflower oil) were purchased from local market of Dharan, Nepal. Recipe for the preparation of sel-roti was Riceflour: 100 g, Sugar: 21 g, Ghee: 10.5 g and Water: 25 mL. Figure.1 shows the method of preparation of sel-roti. The rice was winnowed with the help of Nanglo and cleaned with water for 2 times. Water was added and was allowed to stand for 2 hours. The water was drained from the soaked rice and ground into flour. The flour was sieved by using ASTM standard set of sieve with clear opening of 600 μ (Pradeep Trading Co. Delhi). The flour retained in sieve was collected and weighed. Based on the particle size the rice flour was divided into two groups as coarse (>600 μ) and fine (<600 μ). For the preparation of
"Sel-roti", 30% coarse flour and 70% fine flour were mixed and taken. Sugar, ghee and a little water was added onto the flour. It was kneaded with palm for about 20 minutes and allowed to stand for batter development. Sufficient water was added and whipped with hand. Then, the batter was poured into heated oil, giving into the circular shape. Frying was done at 210°C (initial). Total time of frying was 35 second; upside was turned down after 19 second and finally removed with the help of Jheer, which is a local word for a pointed bamboo stick. After preparing batter as above it was aged at different temperatures for above mentioned time periods. Physical, Chemical and microbial analyses of samples of batter (aged for given time and temperature) were done to study the effect of ageing on the batter.

Sel-roti was made from different samples of "sel-roti" batter and sensory analysis was done to study the effect of batter ageing on sensory quality of "sel-roti".

Fat content of samples of "sel-roti" and rice flour was determined to calculate oil uptake by "sel-roti". Oil-uptake was calculated as follows:

\[
\text{Oil uptake} = \frac{\text{Percent Fat Content}}{100 - (\% \text{Moisture content} + \% \text{fat})} \times 100
\]

(\% Dry & fat free basis)

Bulk density of "sel-roti" was determined by volumetric replacement method using mustard seeds of almost same size as the replacement medium (Nepal Standard 2036 B.S.). A wooden box suitable for the measurement was designed for this purpose. The bulk density of "sel-roti" was calculated using the formula:

\[
\rho_s = \frac{W_s}{W_m} \times \rho_m
\]

Where \(\rho_s\) = bulk density of sel-roti (g/cc);
\(W_s\) = weight of sel-roti (g);
\(W_m\) = weight of mustard seeds with the same volume as that of the Sel-roti (g); and
\(\rho_m\) = bulk density of mustard seeds (g/cc).

Moisture content, protein, reducing sugar, pH and titrable acidity were determined as described in AOAC (2005). Fat, total sugar content was determined by the standard procedure as mentioned in Rangana (2007). Total carbohydrate was determined by difference method. Ash was determined in muffle furnace at 500°C as described in Pearson (1976). Potato dextrose agar and yeast extract-malt extract agar was used for examination of molds and yeasts, respectively. Lactic acid bacteria (LAB) were selectively isolated on MRS agar as described by Harrigan and McCance (1979). Sensory evaluation (by 12 panelists comprising teachers and students of Central Campus of Technology, Dharan) was performed according to 9 point hedonic rating test (9 = like extremely, 1 = dislike extremely) for color, smell, texture, taste and overall acceptance for coded samples rinsing their mouths between tests. Three replicate data obtained was analyzed by ANOVA and t-test using features of GenStat Discovery Edition 3 (GenStat Release 7.22 DE) and means were compared by L S D method at 5% level of significance.

<table>
<thead>
<tr>
<th>Process</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Rice</td>
<td>* for about 2 hours in potable water</td>
</tr>
<tr>
<td>Cleaning</td>
<td>*in Khalbacha or grinder</td>
</tr>
<tr>
<td>Soaking</td>
<td>*ghee and sugar</td>
</tr>
<tr>
<td>Draining</td>
<td>*about 20 minutes</td>
</tr>
<tr>
<td>Grinding/powdering</td>
<td>*Adding water in adequate amount</td>
</tr>
<tr>
<td>Sieving *optimum particle size</td>
<td><em>at 30°C, 40°C and 50°C for 3h</em>, 6h and 9h</td>
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Frying in oil *at initial 210°C, total time 35 second, by turning other side by means of Jheer after 19 second

Sel-roti

Ready to serve

Figure 1. Flow chart for the preparation of sel-roti
Results and Discussion
Composition of sel-roti batter
Table 1 shows the proximate composition of freshly prepared sel-roti batter. The composition was calculated on the average of three samples.

Table 1. Proximate composition of freshly prepared sel-roti batter

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values (%)</th>
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<tbody>
<tr>
<td>Moisture</td>
<td>34.23±0.43</td>
</tr>
<tr>
<td>Total carbohydrates</td>
<td>83.05±0.48</td>
</tr>
<tr>
<td>Protein</td>
<td>5.43±0.32</td>
</tr>
<tr>
<td>Fat</td>
<td>10.65±0.38</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>0.16±0.001</td>
</tr>
<tr>
<td>Ash</td>
<td>0.7±0.015</td>
</tr>
</tbody>
</table>

All values are on dry basis except moisture
Values are arithmetic mean of the triplicate samples ±standard deviation

Effect of ageing on acidity and pH of the Sel-roti batter
The effect of ageing on acidity of the sel-roti batter is presented in Figure 2. Acidity of freshly prepared sel-roti batter was 0.09% (as lactic acid). Yonzan and Tamang (2010) also reported similar value (0.08±0.01). As the time of ageing increased, the acidity in the batter was also increased due to production of lactic acid. Initially the increasing trend was slow where as it is faster at the later periods of ageing. During 9 hour of ageing, the acidity of the batter had increased from 0.09 to 0.15, 0.19 and 0.124 (as lactic acid) for 30°C, 40°C and 50°C respectively. Consequently, there was a gradual fall in the acidity of the batter after 3 hr of ageing time at 50°C. The later slow decrease in the acidity at 50°C might be due to retardation of growth of mesophilic organisms at that temperature. That might be due to proteolysis of protein at that temperature. Moulay et al. (2006), Law and Kolstad (1983), Savijoki et al. (2006) and many others reported the proteolytic activity of lactic acid bacteria. *Leuconostoc mesenteroides, Enterococcus faecium, Pediococcus pentosaceus* and *Lactobacillus Curvatus* are the most dominant lactic acid bacteria of sel-roti batter (Yonzan and Tamang, 2010). Evidence for extracellular proteolytic activity in *Lactobacillus curvatus* was also demonstrated by Pereira et al. (2001).

Effect of ageing on reducing sugar and total sugar content of sel-roti batters
The effect of ageing on reducing sugar and total sugar content of the sel-roti batter is presented in Fig. 4 and Fig. 5 respectively. The initial reducing sugar content of sel-roti batter was found to be 0.33%. During 9 hour of ageing, it had increased to 0.64 %, 0.59 % and 0.75 % for 30°C, 40°C and 50°C respectively. The slightly lower rate of increase of reducing sugar at 30°C and 40°C can be understood as higher rate of consumption of fermentable sugar at these temperatures during ageing.

Total sugar content of sel-roti batter was increased during first 6 hour of ageing from 14.83% to 15.85%, 15.97% and 16.34% for 30°C, 40°C and 50°C respectively. The initial increment of total sugar content indicates hydrolysis of polysaccharides into simple sugar which might be due the effect of enzymes produced by mold present in the sample of sel-roti batter. The later decrease in total sugar content after 6 hour of ageing indicates the utilization of fermentable sugar by microorganisms to produce different metabolites.
Figure 4. Effect of ageing on reducing sugar content of sel-roti batter

Figure 5. Effect of ageing on total sugar content of sel-roti batter

**Bulk density**

Bulk density of samples of sel-roti was determined to study the effect of sel-roti batter ageing on bulk density of product and the effect is presented in Figure 6.

![Figure 6. Effect of batter ageing on bulk density of sel-roti](image)

The bulk density of the product prepared from the fresh sample of sel-roti batter was 0.53 g/cc. The value was near about that found by Katawal and Subba (2011). The above fig 4.5 shows that during the ageing period of 3 hour bulk density of products were decreased for all temperatures of ageing (30°C, 40°C and 50°C). But after 3 hours of ageing it was increased slightly and reached up to 0.52 g/cc for 40°C. There was sharp increment of bulk density of sel-roti prepared from the samples of batter aged at 50°C. The graph shows that there was continuous decrease on bulk density of sel-roti prepared from the sample of batter aged at 30°C. That might be due to the effect of fermentation by yeast as that temperature is optimum for yeast.

**Fat-uptake**

Fat uptake of the products (Dry and fat free basis) prepared from the samples of batters aged for different conditions were shown in Figure 7. The value for the sel-roti from freshly prepared batter was 27.01%. The value was quite lower than that found by Katawal and Subba (2011). Katawal and Subba also reported that sel-roti made from rice flour containing smaller or finer particles absorbs more oil or fat and vice versa. The reason of lower fat uptake of these products was probably due to presence of coarse particle of flour in the recipe.

![Figure 7. Effect of batter ageing on fat-uptake](image)

Figure 7 shows that fat-uptake decreases with increase in ageing time which might be due to production of lactic acid as ageing proceeds. Mahmod et al. (2008) reported that the use of acetic and lactic acid in rice causes a decrease in oil penetration.

**Microbial analysis**

The microbial population of LAB, yeast and mold in freshly prepared batter were $10^4$, $10^3$ and $10^6$ cfu/g of sample. Similar result was found by Yonzan and Tamang (2010) where the microbial populations of LAB and yeasts were $10^4$ - $10^6$ cfu/g and $10^4$ - $10^5$ cfu/g, respectively. The initial mold count of freshly prepared batter was 10^6 cfu/g. Mold was not detected in the sample of batter by Yonzan and Tamang (2010). High mold count in the sample of batter in this study might be due to contamination from sugar used in the recipe.

The effects of ageing on the microbial population of batter were shown in Figure 8, Figure 9 and Figure 10. Figure 8 and Figure 9 show that microbial population of LAB and yeast were increased with ageing period at 30°C and 40°C. LAB and yeast count at the end of 9 hours of aging was higher at 30°C than at 40°C which might be due to more favorable condition of LAB and yeast growth at 30°C than at 40°C. LAB and yeast count at 50°C was markedly decreased during 9 hours of ageing of batter.
as higher temperature retard and even kill vegetative microorganisms.

Figure 8. Effect of ageing on LAB count

Figure 9. Effect of ageing on Yeast count

Figure 10. Effect of ageing on Mold count

Figure 11. Effect of batter ageing on appearance of sel-roti

Figure 12. Effect of batter ageing on smell of sel-roti

Sensory quality of the product

To study the effect of ageing on the sensory quality of the sel-roti, ten products from the samples of batter with different temperature (30°C, 40°C and 50°C) and different time (0 h, 3h, 6h and 9h) of ageing was prepared and sensory analysis of the sel-roti was carried out. The mean sensory scores of the products in terms of appearance, smell, taste, texture and overall acceptability are presented in Fig. 11, 12, 13, 14 and 15 respectively. The mean sensory score in terms of appearance, smell, texture and overall acceptability of the sel-roti prepared from batter aged for 3 hour at 40°C were highest. The score were significantly different (p<0.05) from the mean sensory scores in terms of appearance, smell, texture and overall acceptability of other sel-roti but no significant difference (p>0.05) was observed from the sel-roti prepared from the sample of batter aged for 6 h and 9 h at 30°C. The mean sensory score in terms of taste of the sel-roti prepared from the batter aged for 3 h at 50°C was highest. That might be due to higher amount of residual sugar present in the batter. That score was significantly different (p<0.05) from the mean scores of taste of other sel-roti but no significant difference (p>0.05) was observed from the sel-roti prepared from the samples of batter aged for 6 h and 9 h at 30°C and 3 h and 6 h at 40°C.
Fig. 13 Effect of batter ageing on taste of sel-roti

Figure 14. Effect of batter ageing on texture of sel-roti

Figure 15. Effect of batter ageing on overall acceptability of sel-roti

Conclusions

As the time of ageing increased the acidity of the batter increased and pH decreased. During 9 hours of ageing, reducing sugar content of batter increased but total sugar content of batter increased up to 6 hours and then started to decrease. Sel-roti prepared from batter aged up to 3 h had lower bulk density. The bulk density increased after 3 hours of ageing at 40°C and 50°C. Sel-roti prepared from batter aged for 3 hours at 40°C and 50°C had higher fat uptake. Sel-roti prepared from batter aged at lower temperature i.e. 30°C or 40°C and 50°C for more than 3 hours had lower fat uptake. Lactic acid bacteria, yeasts and mold co-existed in Sel-roti batter enhancing the sensory quality of the product. Batter ageing had significant effect on quality of sel-roti. Among study time and temperature of ageing quality of sel-roti prepared from batter aged at 30°C for 6 h was found to be good in terms of sensory quality and cost effectiveness.

References


