Development of a rice incorporated synbiotic yogurt with low retrogradation properties

Kumari, A. G. I. P. 1Ranadheera, C. S., 1Prasanna, P. H. P., 2Senevirathne, N. D. and 2Vidanarachchi, J. K.

1Department of Animal & Food Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Anuradhapura, 50000, Sri Lanka
2Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, 20400, Sri Lanka

Abstract

Yogurts with probiotic Bifidobacterium animalis subsp. lactis BB-12 were prepared using cow’s milk and boiled rice (13% wt/wt) was incorporated into yogurts at the end of the incubation period. Four rice varieties namely, At-309, At-405, MA-2 and Thai Jasmine (KDML 105) were used for the study. Microbial, physico-chemical and sensory properties of rice yogurts were evaluated during 21 days of storage at 4°C. Incorporation of rice into yogurts significantly improved the crude fiber contents (p<0.05) of yogurts. All rice incorporated yogurts showed higher water holding capacity compared to that of plain yogurts (without rice) throughout the storage. Titratable acidity, viscosity and hardness of yogurts demonstrated the similar trends. Bifidobacterium counts of the rice incorporated yogurts were higher (>8 cfu.g⁻¹) than that of plain yogurts at the end of storage period, probably due to prebiotic effect of rice. There were significant differences among the yogurt samples for evaluated sensory characteristics and At-405 rice yogurt demonstrated the lowest overall sensory acceptability. Therefore, careful selection of suitable rice varieties is vital in producing symbiotic rice yogurt with high quality.

Keywords

Rice
Bifidobacterium
Fermentation
Food quality
Probiotics

Introduction

Probiotics are live microorganisms when administered in adequate amounts confer health benefits on the host (FAO/WHO, 2002). The reported beneficial effects of probiotic consumption include improvement of intestinal health, amelioration of symptoms of lactose intolerance, enhancement of the immune response, reduction of serum cholesterol, control of urogenital and respiratory tract infections, and reduction of the risk of colon cancers (Salminen et al., 2005; Vasudha and Mishra, 2013; Prasanna et al., 2014). Therefore, probiotics such as lactobacilli and bifidobacteria incorporated food products are popular among health conscious consumers (Ranadheera et al., 2014). Yogurt is a fermented dairy product produced by fermentation of milk using starter culture bacteria Streptococcus thermophilus and Lactobacillus bulgaricus subsp. delbrueckii. In addition, probiotic bacteria are also included in certain yogurts, hence can be considered as one of the most common carrier foods of probiotics to humans.

Rice is a nutritious cereal and one of the cheapest and major sources of food energy and protein for many people in the world. Brown rice contains nutritional components, such as dietary fibers, essential amino acids, minerals, proteins, vitamins and other non-nutrient essential phytochemicals, concentrated in the germ and outer layers of the starchy endosperm (Kohama et al., 1987). The bran layer of rice kernel contains high level of bioactive compounds such as γ-oryzanol, anthocyanins and phenolic compounds which may reduce low-density lipoprotein cholesterol, improve lipid profiles and have anti-inflammatory and anti-oxidative activities which may help to fight against heart diseases and prevent diabetes (Nontasan et al., 2012). Rice, especially the bran contains dietary fibers which can have beneficial effects against chronic diseases such as cardiovascular diseases, diverticulosis, diabetes and colon cancer (Abdul-Hamid, 2000). Amarakoon et al. (2013) demonstrated that cooked rice facilitates the growth and survival of probiotic bacteria such as bifidobacteria in yogurt. Therefore, beneficial health effects of probiotic yogurts can be further enhanced by incorporation of rice into yogurts. The nutritional quality of rice based foods can also be improved through fermentation by amyololytic lactic acid bacteria such as certain strains of lactobacilli and bifidobacteria which may increase the availability
of lysine and improve the digestibility of starch in young children (Gobbetti et al., 2005; Espirito-Santo et al., 2014). Nowadays, cereals alone or mixed with other ingredients are widely utilized in producing novel food products with enhanced health properties (Blandino et al., 2003; Coda et al., 2012). Nontasan et al. (2012) recently developed a yogurt with good color stability and higher levels of phytochemicals using black waxy rice bran. However, Amarakaon et al. (2013) reported significantly higher hardness development in rice incorporated yogurts compared to plain yogurts during refrigerated storage possibly due to retrogradation of rice.

Rice starch is made up of two polysaccharide types called amylose and amylopectin (Fredriksson et al., 1998). During cooking, hot water enters the semi-crystalline regions of raw rice starch, breaks down the intermolecular hydrogen bonds, and binds to the hydroxyl hydrogen and oxygen hence the chains of starch lose their crystallinity into the amorphous form. This gelatinized starch is not in thermodynamic equilibrium. During cooling or being left at a lower temperature for long periods, the linear molecules, amylose, and the linear parts of amylopectin molecules expel water and rearrange themselves again to a more crystalline structure. This recrystallization is known as retrogradation, resulting in hard and amylase-inaccessible textures with poor sensory quality and low nutritional value in cooked rice (Chung et al., 2006, Okuda et al., 2006; Zhu et al., 2013; Li et al., 2014). Therefore, retrogradation process is highly likely to affect the organoleptic and nutritional qualities and reduces the consumer acceptability of rice incorporated yogurts. To the best of our knowledge, very few studies investigated the quality of rice incorporated probiotic yogurts. Our preliminary studies demonstrated that the use of low-amylose rice varieties can be successfully utilized in producing rice incorporated yogurt with low retrogradation properties. This study aimed to develop rice incorporated synbiotic yogurt with acceptable organoleptic properties by using low-amylose rice varieties.

Materials and Methods

Yogurt production

The experiment was conducted at the Dairy Science Laboratory, University of Peradeniya, Sri Lanka. Fat content of cow’s milk (Livestock Field Station, University of Peradeniya, Sri Lanka) was adjusted to contain 3.2% by adding skimmed milk (provided by the Livestock Field Station, University of Peradeniya, Sri Lanka). Sugar (20% wt/wt) and gelatin (0.5% wt/wt) (Central Essense Pvt. Ltd, Kandy, Sri Lanka) were also added before the yogurt mix was homogenized at 200 bar pressure for 30 min using a homogenizer (Tessa JJ05125, Israel). The yogurt mix was pasteurized at 91°C for 5 min using a double jacketed heating vat (Tessa NMRV063, Israel). The pasteurized mix was cooled to 42°C using a plate heat exchanger (Tessa plate 11+11, Israel). STI 12 culture granules containing yogurt starter culture Streptococcus thermophiles (CHR Hansen, Denmark) and probiotic Bifidobacterium animalis subsp. lactis BB-12 (CHR Hansen, Denmark) were inoculated as a direct vat set (DVS) into the yogurt mix as per the manufactures recommendations. Then the mix was incubated at 42°C for 3-4 hrs until reaching ~ 4.6 pH.

Through preliminary trials four low amylose rice varieties (Oryza sativa L.) were selected to be incorporated into yogurt mixture (Thai Jasmine rice-KDML 105 with 12%-17% amylose content and three local verities MA-2, At-309 and At-405 with < 22% amylose contents). Thai Jasmine rice was purchased from Arpico Supermarket, Kandy, Sri Lanka while local rice varieties were obtained from Rice Research Institutes (RRI) of Sri Lanka (MA-2 from RRI, Bathalagoda, Sri Lanka and At-309 and At-405 from RRI, Ambalantota, Sri Lanka). After incubation, the yogurt mixture was divided into four batches aseptically and respective pressure cooked rice varieties were added as 13% (wt/wt) into the incubated yogurt and stirred well approximately for 3 min. After mixing yogurt were filled into the plastic cartons (80 g) and stored at 4°C.

Physico-chemical properties

Total solid content (oven dry method), fat content (Gerber method) pH (by using a digital pH meter, eutEch Instruments Pvt.Ltd, Singappore) and titratable acidity (by titraing against 0.1 N NaOH in the presence of phenolphthalein) of raw cow’s milk were measured prior to yogurt production (AOAC, 2005).

Total solids (oven drying method), ash content (ignition of solid materials at 600°C in an electric muffle furnace, Carbolite Co., England), protein (Kjeldhal method), fat content (Soxhlet extraction method) and crude fiber contents of the yogurt samples were analyzed during the storage (AOAC, 2005). The titratable acidity and pH of yogurt samples were also measured during the storage as previously described. In here, yogurt without any added rice was also used to evaluate the nutritional changes that may be caused by addition of rice into yogurt.

Water holding capacity (WHC) of rice yogurt
samples was measured by a method reported earlier (Isanga and Zhang, 2012) with slight modifications. Ten grams of yogurt was measured into an oven dried centrifuge tube and centrifuged at 4600 rpm for 30 min and the WHC was calculated as follows:

\[ \text{WHC (\%)} = (1 - \frac{W_1}{W_2}) \times 100 \]

Where: \( W_1 = \) Weight of whey after centrifugation, \( W_2 = \) Initial weight of yogurt sample.

Viscosity of rice yogurts was measured as described by Ranadheera et al. (2012) with small modifications using a viscometer (BL model Tokimec, Japan). Viscosity was determined based on measuring resistance to a rotating spindle (Spindle no. 4 at 12 rpm) at constant temperature (4°C) for 5 min in a yogurt filled 6.36 cm diameter 6 cm height cup.

Texture hardness in rice yogurts was measured as described by Alfaro et al. (2015) with small modifications using an Instron machine texture analyser (Instron 4465, Japan) with a 2 KN launch cell. Yogurt samples produced in a cylindrical container (6.36 cm diameter 6 cm height) and force needed to destruct the gel (force per area) was measured in N. A 38 mm in diameter flat base cylinder with a constant speed of 150 mm/min was thrust into the cylindrical container in order to measure the texture hardness of yogurt.

Sensory properties

Sensory evaluations were conducted to evaluate the color, odor, texture, flavor and overall acceptability of rice yogurt samples at 7 and 14 days of the storage as described by Stone et al. (2012) with slight modifications. Sensory attributes were evaluated through a 1-4 scale (4- most preferred to 1- least preferred) with 30 untrained panellists. The panel was randomly selected among the students and staff members of the Faculty of Agriculture, University of Peradeniya, Sri Lanka, based on their willingness to participate the study. The samples (80 g each) were served in white color cups with randomly selected three digits numbers for the evaluations. The sensory evaluation procedure was approved by the Department of Animal and Food Sciences, Rajarata University of Sri Lanka.

Bifidobacterium viability in yogurt and yeast, mold and coliform counts

Microbial analyses of the yogurt samples were conducted on day 1, 7, 14 and 21 during the storage. Bifidobacterium agar (Himedia laboratories, India) was used to enumerate Bifidobacterium animalis subsp. lactis BB-12. One gram of yogurt sample was serially diluted in sterile peptone water and enumeration was done using the pour plate technique. The plates were incubated at 37°C for 72 hrs in anaerobic jars (Oxoid Ltd, Hampshire, UK) with an anaerobic environment (<1% O₂ and 9-13% CO₂), generated using anaerobic AnaeroGen® sachets (AN0025A, Oxoid Ltd, Hampshire, UK). Enumeration of yeast and mold was conducted in Potato Dextrose Agar (PDA) using spread plate technique. The plates were incubated at 25°C for 5 days. Enumeration of Coliform was conducted in Violet Red Bile Agar using spread plate techniques following aerobic incubation at 35°C for 5 days. Viable bacteria counts were expressed as log cfu.g⁻¹ of yogurt sample.

Statistical analyses

The data from the sensory evaluations were analyzed using non parametric Friedman test and physico-chemical and microbiological results in triplicates were analyzed by one way ANOVA for Completely Randomized Design using MINITAB software. The means were separated by Tukey test. A p value <0.05 was considered statistically significant for all analysis.

Results and Discussion

Physico-chemical properties of yogurt

Titratable acidity, pH, total solid and fat contents of cow’s milk used to produce rice incorporated yogurts were 0.16±0.01%, 6.24±0.02, 13.65±0.43% and 3.70±0.05%, respectively. Physico-chemical properties of different rice incorporated yogurts are shown in Table 1. As expected, the total solids content was lowest in plain yogurt, because no added rice in plain yogurt. The average fat and protein contents were also lowest in plain yogurt. Incorporation of At-309 and At-405 rice have significantly increased (p<0.05) the protein content of yogurts. The crude fiber content of rice yogurts were within the range of 1.12-1.49% whereas no fiber was present in plain yogurt. Incorporation of rice into the yogurt had significantly increased (p<0.05) the fiber content of yogurt compared to that of plain yogurt.

Figure 1 shows the variations of physico-chemical properties of plain and rice yogurts during the storage period. pH value of all yogurts decreased with the time up to 16th day and started to slightly increase thereafter. Present trend agrees with Vahedi et al. (2008) and Ranadheera et al. (2012) who reported that pH values of fruit yogurt decreased during storage
Table 1. Physico-chemical properties of plain and rice incorporated yogurts

| Thai rice yogurt | MA-2 rice yogurt | At-309 rice yogurt | At-405 rice yogurt | Plain yogurt | Mean±SD
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>22.45±4.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.85±0.48&lt;sup&gt;b&lt;/sup&gt;</td>
<td>23.23±0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.28±0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.58±2.99&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>2.75±4.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.84±0.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.69±0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.85±0.38&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.75±0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>3.26±0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.27±0.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.65±0.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.51±0.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.14±0.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>3.63±0.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.28±0.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.75±0.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.73±0.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.24±0.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>1.12±0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.36±0.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.46±0.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.49±0.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.00±0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

Values in the same rows having different superscripts are significantly different (p<0.05).

Figure 1. Variations of some physico-chemical properties of plain and rice yogurts during storage: (A) pH, (B) Titratable Acidity, (C) Water Holding Capacity, (D) Viscosity and (E) Texture Hardness.
and slightly increased at the latter part of storage. Decrease of pH may be due to increase of lactic acid production by lactic acid bacteria. As sugar sources finish, microorganisms begin to consume proteins and producing some products such as peptides by microorganisms as a result of biochemical metabolism, may cause slight pH increase at the later part of storage (Vahedi et al., 2008). The pH values of all the rice yogurts were within generally acceptable level for yogurt during the storage.

Titratable acidity of all the yogurt samples were within the recommendations (0.8-1.25%) given by Sri Lanka Standards Institute (1989) and increased during storage period. Similar trend was observed by many authors for fermented dairy foods (Vahedi et al., 2008; Güler and Gürsoy-Balcı, 2011; Ranadheera et al., 2012). The increase in titratable acidity during storage could be attributed to the activity of S. thermophiles and Bifidobacterium cultures used in the present study. It is widely accepted that lactic acid bacteria usually convert lactose into lactic acid and thereby increase the acidity in fermented dairy foods. Higher titratable acidity values were observed for rice yogurts compared to plain yogurt throughout the storage. Sandra et al., (2008) previously demonstrated the positive effect of fiber extracted from lemon and orange juice by-products on the growth and survival of L. acidophilus and B. bifidum in fermented milk during incubation and refrigerated storage. Similarly, fiber in rice might have improved the growth and activity of lactic acid bacteria in the rice yogurt and thereby higher lactic acid production in rice yogurts than in plain yogurt might be possible. This hypothesis is further supported by the higher survivability of bifidobacteria in rice yogurts compared to plain yogurt in the present study (Figure 2). The highest titratable acidity was observed in the At-405 rice yogurt throughout the storage period. Among all the rice yogurts, the highest crude fiber content (Table 1) was also observed in At-405 rice yogurt, demonstrating the effect of fiber towards increasing titratable acidity in probiotic dairy foods possibly through promoting the growth of lactic acid bacteria during storage.

Usually higher acidity stimulates the whey separation in yogurts (Tamime and Robinson, 1999). Although rice yogurts demonstrated higher acidity, less whey separation or higher WHC in rice yogurt compared to plain yogurt was observed during the storage in the present study. This may be probably due to high total solids (Remeuf et al., 2003) and fiber content in the rice yogurt (Table 1) which could have strengthened the yogurt gel structure in rice yogurts and thereby making less susceptible to loose whey under centrifugal force. Fiber components can improve the texture, gelling, thickening and stabilizing properties in food products (Abdul-Hamid, 2000). Furthermore, Shori et al. (2014) have suggested that exopolysaccharides produced by bacteria in the yogurts, which act as hydrocolloids help to increase WHC in yogurts. B. animalis subsp.
lactis is known to produce exopolysaccharides (Prasanna et al., 2014) and higher viable numbers of Bifidobacterium was observed in rice yogurt than in plain yogurt in the present study (Figure 2). Therefore, the amount of exopolysaccharides production by bifidobacteria might have been high in rice yogurts than in plain yogurts. Similar to the findings from the current study, increasing trend in WHC during storage of control and calcium fortified fruit yogurts has previously been reported by Singh and Muthukumarappan (2008). Increase in WHC as the storage time progresses could also be due to re-absorption of whey back into the yogurt gel (Cassarotti, 2014). In contrast, Küçükçetin et al. (2011) reported the decreasing trend in WHC of yogurt gel during 15 days of storage at 4°C. Previous studies also have reported that the effective immobilization of the aqueous phase by the gelatin in the yogurt could significantly reduce the whey separation from yogurt and gelatin may induce the formation of a gel network with the sodium caseinate in the yogurt mixture (Lal et al., 2006; Supavitipatana et al., 2008). In the present study gelatin was added into the yogurt as a stabilizer during manufacturing and this might also have been a reason to observe increasing WHC in yogurts during the storage.

As shown in Figure 1 there was an increasing trend in viscosity of yogurts with time. All the rice incorporated yogurts exhibited higher (p< 0.05) viscosity values throughout the storage period. High total solid contents in rice yogurts could be suggested as a reason for increased viscosity in rice yogurts in the present study. According to Tamime and Robinson (1999), increasing total solid content in yogurt could result higher consistency and viscosity values. In the present study total solids in rice yogurts were within the range of 22.45±4.63 - 24.28±0.31% while total solid content in plain yogurt was 16.58±2.99% (Table 1). Other than the total solid content, some researchers claim that viscosity and texture of yogurt is positively affected by the microbial exopolysaccharide produced by lactic acid bacteria in yogurt since exopolysaccharides may act as texturizers and stabilizers (Duboc and Mollet, 2001). Therefore, exopolysaccharides may increase the viscosity of the final product as well as the rigidity of the casein network by binding hydration water and interacting with other milk constituents such as proteins and micelles. Thus, higher viability of B. animalis subsp. lactis BB-12 in rice yogurts compared to plain yogurt in the present study (Figure 2) might have been responsible for the increasing viscosity values in rice yogurts through production of exopolysaccharides. Retrogradation process of rice may also have influenced the viscosity of rice yogurt.

The force needed to puncture the yogurt gel (hardness value) was increased with time in the present study. The rice incorporated yogurts demonstrated higher texture hardness compared to plain yogurt throughout the storage period. High total solid and fiber contents of rice yogurts (Table 1) might have been affected to texture hardness similar to viscosity and WHC in the present study. Higher total solid contents decrease the moisture content of food products. Moisture content and the total solids affected on the texture, whereas low moisture content and high total solid may increase the texture hardness and consistency of food products such as yogurts. Moreover, from 7th day onwards, At-309 and Thai rice yogurts showed significantly lower (p<0.05) force to disturb the yogurt gel compared to that of other two local rice incorporated yogurts. The reason might be the soft texture of the At-309 and Thai rice yogurts compared to other local rice incorporated yogurts possibly due to low retrogradation rate of At-309 and Thai rice compared to other local rice varieties.

Sensory properties of yogurt

There were significant differences among yogurts for sensory parameter during the storage (Table 2). At-309 rice yogurt scored the highest average rank for the color during the storage while At-405 rice yogurt demonstrated the lowest overall acceptability for tested sensory characteristics probably due to its natural brownish color. When consider texture, both Thai jasmine rice and MA-2 rice yogurts scored the highest average rank, while At-309 rice yogurt scored the highest overall acceptability at the day 14th of storage.

As reported by Amarakoon et al. (2013), the sensory characteristics of cooked rice varieties directly affect the overall sensory properties of rice incorporated yogurt. Sensory properties of rice can be influenced by many factors such as contents of amyllose and protein contents, charlky grain rate, pasting properties, springiness and stickiness (Yang et al., 2013), hardness, storage duration and conditions. Clearly, little is known concerning the effect of physico-chemical and sensory properties of various rice varieties on the consumer acceptability of rice incorporated yogurts, suggesting necessity of more scientific research towards rice incorporated symbiotic yogurts.

Viability of bifidobacteria in rice yogurt

It is reported that the yogurts containing live probiotics confer health benefits to the host when they are consumed in appropriate quantity (Mckinley,
2005). Thus, it is necessary for probiotic cultures to survive in yogurts during their shelf life prior to being consumed. It is generally accepted that a concentration of approximately $10^6$-$10^7$ viable cells per g or mL of product at the time of consumption is beneficial to confer health effects in humans.

Since At-405 rice variety showed the least consumer acceptability for most sensory attributes, At-405 rice incorporated yogurts did not include in assessing bifidobacteria viability. Only the control, and two other rice yogurt samples representing one local rice variety (At-309) and the imported rice variety (Thai Jasmine rice) which demonstrated an appropriate sensory acceptability were included in this study. B. animalis subsp. lactis BB-12 counts in yogurts slightly increased up to 7th day of storage and gradually decreased thereafter in the present study (Figure 2). In At-309 rice yogurt, initial Bifidibacterium count (8.59±0.69 log cfu.g$^{-1}$) was decreased to 8.50±0.51 log cfu.g$^{-1}$ while in Thai rice yogurt, initial Bifidibacterium count was decreased from 8.40±0.57 log cfu.g$^{-1}$ to 8.38±0.45 log cfu.g$^{-1}$ at the end of storage. Highest viability loss for bifidobacteria was observed in plain yogurt. Initial Bifidibacterium count in rice yogurt (8.29±0.58 log cfu.g$^{-1}$) was decreased to 7.26±0.47 log cfu.g$^{-1}$ at the end of storage. Parmijit et al. (2011) suggested that the reduction of Bifidibacterium viability during storage might be attributed to hydrogen peroxide produced by starter culture Lactobacilli. On the other hand Bari et al. (2009) reported that the dissolved oxygen content might directly affect the survival of probiotic cultures. According to Champagne et al. (2005) oxygen affects the probiotic cultures in two ways. The first is direct toxicity to cells. Certain probiotic cultures are very sensitive to oxygen and die in its presence, presumably due to the intracellular production of hydrogen peroxide. When oxygen is in the medium, certain cultures, particularly, yogurt starter culture L. delbrueckii, excrete peroxide in the medium and thereby indirect inhibition of probiotics such as Bifidibacterium may also occur.

In the present study, despite the decrease of viable cell count with storage time, Bifidibacterium count in both rice and plain yogurts were able to maintain the minimum recommended therapeutic level. There were no significant differences (p>0.05) in Bifidibacterium counts among yogurts at the day of production. However, rice yogurts recorded significantly higher (p<0.05) Bifidibacterium counts during the refrigerated storage compared to that of plain yogurt demonstrating certain prebiotic effect of rice towards bifidobacteria.

**Yeast and mold and coliform counts in yogurts**

Undesirable levels of yeast and molds (>10$^2$ cfu.g$^{-1}$) (SLSI, 1989) were not recorded in any yogurt sample in the present study. Although it was not significantly difference (p>0.05) yeast and mold growth was slightly higher in rice yogurts than in plain yogurts, probably due to contamination during rice incorporation into yogurt. No coliform bacteria were detected in any of the yogurt samples due to employment of good hygienic practices during the manufacturing of yogurt in this study.

**Conclusions**

Incorporation of rice into probiotic yogurts seemed beneficial in improving the fibre content of yogurts. Generally, rice incorporated yogurts demonstrated higher total solids, fat, protein content, titratable acidity, water holding capacity, viscosity and texture hardness compared to plain yogurts without rice. Rice incorporated yogurts were within the acceptable pH range and their sensory properties were varied based on the rice varieties used. Rice yogurts demonstrated the ability in maintaining higher viability of probiotic B. animalis subsp. lactis BB-12 than plain yogurts during 21 days of storage at 4°C suggesting favorable prebiotic properties in rice. Therefore, it is possible to produce high quality symbiotic yogurts through incorporation of cooked rice into yogurts. However, careful selection of suitable rice varieties is necessary in order to maintain the satisfactory quality characteristics during storage.

**Acknowledgements**

Authors gratefully acknowledge the technical assistance provided by Mr. A.K.P. Chandrapala and the technical staff of the Department of Animal Science, University of Peradeniya, Sri Lanka throughout this research project.

**References**


Remeuf, F., Mohammed, S., Sodini, I. and Tissier, J. P. 2003. Preliminary observations on the effects of...
milk fortification and heating on microstructure and physical properties of stirred yogurt. International Dairy Journal 13(9): 773-782.


