REUSE POTENTIAL OF CLAY POTS FOR PACKAGING OF CURD

Dunu Arachchige Nimal Dharmasena,
Department of Agricultural Engineering, University of Peradeniya
dand@pdn.ac,lk
Kottapola Gedara Janaka Prasad Kottapola,
Department of Agricultural Engineering, University of Peradeniya
jkottapola@gmail.com
Kahandage Francis Sarles Tilak Silva
Department of Animal Science, University of Peradeniya
frankserendib@gmail.com

Abstract

A Buffalo curd packed in a clay pot is one of the most traditional dairy products in Sri Lanka. Although both clay pots and plastic cups are used for packaging of curd, the clay pot is the most popular package. However, the clay pot is disposable and become a waste after a use. This unsustainable consumption of limited clay resource is not environment friendly and cost effective. Re-using clay pots after re-firing will protect the earth while enhancing profit to the curd producer. Therefore, the main objective of this study was to evaluate the effect of re-firing of used curd packing clay pots on physical & microbiological qualities, quality of curd and analyze the possible energy saving. A Completely Randomized Design (CRD) was used for the experiment with four treatments and eight replicates. The treatments are; Re-firing of used pots only once, twice, thrice and the control (new pots). Pots were re-fired at 800 ^{0}C for one hour using a muffle furnace. Then the physical properties: weight, colour and compressive strength were measured. The initial microbial loads were tested by plate counts. Mold growth on curd was visually observed and pH was also measured to evaluate the shelf life of curd. According to the results, re-firing improved the red colour while reducing initial microbial counts. There was no effect on compressive strength and pot weight. The porosity of pots increased with re-firing. This led to excessive water loss resulting pH reduction of curd after third firing. Mold growth on curd was not observed for 12 days. Therefore, pots can be re-used at least twice after proper re-firing and there by 34% of total energy and 2/3rd of clay resources can be saved in the curd industry.

Key words: Clay pots, Curd packaging, Re-use, Re-firing, Energy saving

1. Introduction

Curd is the fermented milk product obtained from coagulation of cow's or buffalo's milk and should have pleasant odour, a characteristic flavour and absence of extraneous matter. The basic requirements (percent by mass) of curd and buffalo curd are: Milk fat, 5.0, 7.5, Milk Solids Non Fat, (MSNF), 8.5, 8.5 respectively, and the maximum pH of 4.5 for both types. There should not be any coliform bacteria in 1g of curd **(**Food (Standards) Regulations 1989). The annual buffalo milk production in Sri Lanka is about 49,251,360L in 2009 (Department of Census and Statistics Sri Lanka, 2009) and almost all of this volume is processed into curd and packed using at least fifty million clay pots.

In Sri Lanka, the most popular traditional packing material in the local market is the traditional clay pot which is classified under earthenware in food industry. Earthenware has a dusty rough surface and can also absorb water from food materials. Earthenware clays contain a relatively high amount of iron oxide and during firing the clay pottery brick red colour is developed due to oxidation (Conway, 1976). The finished clay pots are fired at a high temperature, between 600 and 1250°C (Axtell and Follows, 1993).

Plastic cups (PP) are also used for curd packaging in domestic markers but, it gives a poor texture to the curd and also it is not eco-friendly compared to clay pots as it consumes 121MJ/kg of energy during the lifecycle in addition to the energy used for transportation which accounts for 0.5MJ/t. km. However, clay pots are disposable and used only once for curd packaging at present and improper waste discharge facilitates mosquito breeding in most of the ecosystems. This kind of usage is neither environment friendly nor cost effective and unsustainable use of a limited clay resource. Thousands of clay pots are accumulated in sales centers and systematically packed used pot is a way of advertising curd especially in roadside sales centers. Reuse of used clay pots at least once is a great saving not only for the curd industry but also for the environment as it is helpful in sustainable use of limited clay reserves and reduces the environmental pollution by minimizing the energy use in clay mining and pot manufacture.

Therefore, the objective of this research was to evaluate the potential of re-firing of used clay pots for curd packaging with the specific objectives of evaluating the effect of re-firing on: its physical properties, initial microbial loads and to evaluate the effect of re-burned pots on quality of the curd. Further, the energy and material saving due to re-firing was also assessed to analyze the minimization of environmental pollution due to reuse.

2. **Materials and methods**

2.1 Re-firing of used clay pots

The clay pots are usually fired in traditional kilns at a high temperature, between 600 and 1250 °C (Axtell and Follows, 1993). When firing clay pots at different temperatures, different reactions occur and give appropriate properties to clay pots. The various reactions occurring at different temperatures are: at 100 **^{0}C** any remaining atmospheric water converts to steam, at 220 **^{0}C,** when cooling cristobalite suddenly shrinks, at 300 – 800 **^{0}C,** burn off of carbon sulfur and organics, at 350 – 800 **^{0}C,** chemically combined water driven off, at 573 **^{0}C, q**uarts inversions occurs, at 900 **^{0}C**, sintering begins to occur and 1165 **-**1210 **^{0}C,** mid-range vitrification range and high iron content clays begin to melt (The American Ceramic Society, 2005). Based on the above information clay pots collected from a milk bar were re-burned at 800 ^{0}C for one hour using a muffle furnace as chemically combined water's bond loosens and the carbon, sulfur and all organics burn off between 300 – 800 ^{0}C. It took around three hours to reach that temperature in the furnace. Then kept on burning at 800 ^{0}C for one hour and allowed to cool down in the furnace as shown in the following figure (Figure 1).

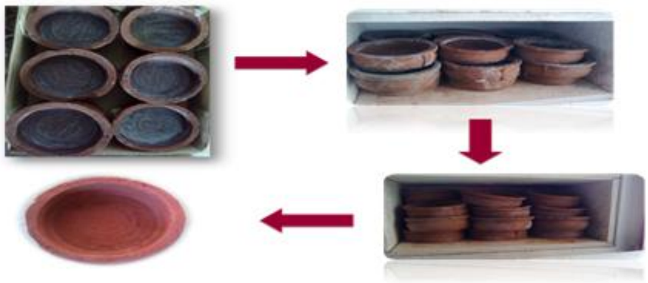

Figure 1: Changers of the appearance of used clay pots during re-firing process

2.2 **Experimental design**

The experimental design used was a Complete Randomized Design (CRD). The following four treatments (T_1, T_2, T_3 and T_4) were used with eight replicates.

T1 – Re-firing of only once used clay pots (pot used twice)

T2 – Re-firing of twice used clay pots (pot used thrice)

T3 –Re-firing of thrice used clay pots (pot used for four time)

T4 – control (unused virgin clay pots)

The experimental process is summarized in the following diagram (Fig. 2).

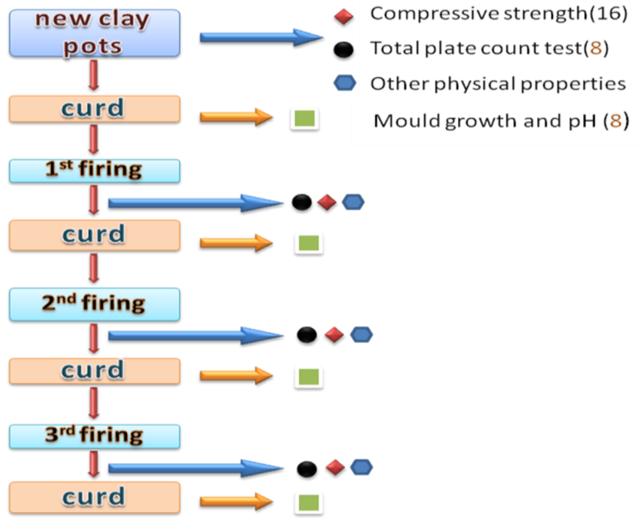

Figure 2: The experimental process flow diagram and number of post used for each test

2.3 Testing of the compressive strength of clay pots

Compressive strength of clay pots were tested by using a dial type dynamometer model; Dillon, van nuys, Califoniya, U.S.A. Clay pots were compressed between two flat plates keeping the bottom of the pot on the lower plate and the upper brim on the upper plate and crushing strength was recorded at first cracking. Test was done for dry clay pots at 25 ± 2 ^{o}C and 80% RH (without soaking them in water) after each firing and for the new clay pots (virgin pots) of the same batch. Strength under wet condition was also measured for water saturated clay pots by keeping them in water for 24 hours.

2.4 Measurement of weight changers of pots

Weight of dry and wet (water saturated) pots were measured using a digital electric balance for virgin pots and re-fired pots after each firing. Dry weight was measured after firing and cooling, and wet weight was measured after one day saturation and removing the surface water. Water holding capacity of pots was calculated using the collected weight data of dry and saturated pots at each re-firing.

2.5 Measurement of colour changers of pots

Colour was measured using a Minolta colour meter; model CR 300, pots under dry and wet conditions for virgin pots and after each firing using the a*, b* and L* colour space. Since the redness of the pot is the most important quality parameter, hue angle was calculated using the following equation (Eq-1) and changers were compared separately for dry and wet pots.

$h_{ab} = tan^{-1} (b^*/a^*)$ - -- (1)

2.6 Microbial sample collection from empty pots

According to Knox and walker (1947), to take samples from a container, the method of washing with Ringer solution was used. One tablet of Ringer was dissolved in 500mL of distilled water to prepare the Ringer solution. Cotton swabs were used to rub the clay pots. Ringer solution and swabs were sterilized in an autoclave at 121°C, 1.03 x 10^5 Nm^2 pressure for 15 minutes prior to use them. A measured volume of 10mL of Ringer solution was poured into a clay pot and washed it with ringer solution by rubbing over the surface of the clay pots using cotton swabs. Sample of 0.1mL was taken from the solution in the clay pot by using a micropipette for the plate count test.

2.7 The plate count test

Plate count agar was added to distill water and stirred well. Then the mixture was boiled until the content dissolved while stirring. Melted agar was cooled to 45°C before plated. A dilution series of microbial solution (10^{-1} – 10^{-3}) was prepared. Petri dishes were labeled and 0.1mL of well mixed samples was transferred from prepared dilution series into Petri dishes using a micropipette. Melted agar was poured into Petri dishes, approximately 15mL per one dish and mixed for uniform spreading, then allowed for hardening. The plates were incubated keeping upside down at 42°C for 24 hours in an incubator and then colonies were counted.

2.8 Inspection of mold growth and measurement of pH of the curd packed in clay pots

The pots were labeled according to the type of the treatment. A prepared curd mixture was poured into each pot in equal volume and covered them with clean polythene sheet. Just after filling, the pots were transferred into an incubator and incubated at 42°C for 2 hours and then they were transferred to a cold room and kept at 4°C. First observation and pH measurements were made after 3 days of incubation and the test was repeated in 2 day intervals up to13th day for all four pot treatments. Sterilized laboratory equipments were used to collect samples from curd pots to avoid unwanted contaminations. The pH value was measured by using an electronic pH meter and the mould growth on curd was visually observed.

3. Results and discussion

3.1 Effect of re-firing on Compressive strength of clay pots

Figure 3 illustrates the mean compressive strengths of dry and wet pots under different treatments. The highest value of compressive strength of dry pots was observed in the virgin pots (control) and the lowest strength value was found in the 3rd fired clay pots while the highest value of compressive strength of saturated pots was observed in the 3rd fired and the lowest was in the 2nd fired clay pots. However, there is no significant difference among four treatments in the dry clay pots as well as water saturated wet clay pots at $p>0.05$. Therefore, Re-firing has no any significant effect on the compressive strength of clay pots at dry stage or saturated stage.

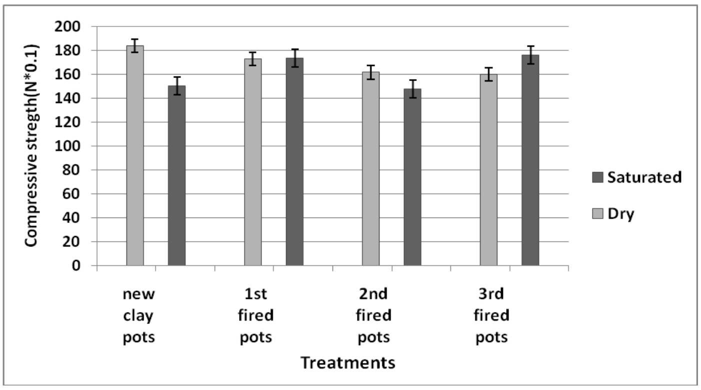

Figure 3: Mean compressive strengths of saturated and dry clay pots after each re-firing

3.2 Effect of re-firing on weight of pots

Figure 4 shows the mean weights of dry and saturated (150ml) clay pots. Generally, saturated weight of pots is higher than the dry pots and the average water holding capacity is 129.5g of water per 1kg of pot. There was no significant difference in weight of clay pots among four different treatments at $p>0.05$. Therefore re-firing has no significant effect on weight of clay pots.

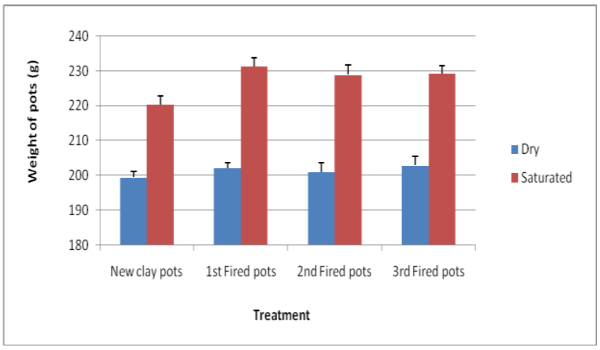

Figure 4: Effect of re-firing on mean weight of clay pots

3.3 Effect of re-firing on water holding capacity of clay pots

Figure 5 illustrates the variation of water holding capacity of clay pots under different treatments. The water holding capacity is an indication of the availability of micro pores in the pot. According to figure 5, water holding capacity of new clay pots is less than the water holding capacity of other three treated pots. There is a significant difference between water holding capacity of new pots to the water holding capacity of other three re-fired pots at $p>0.05$. This indicates that re-firing increases the porosity by further burning of remaining organic matter and other burnable compounds like sulfur at 800 ^{o}C. Although porosity of the pot is a required property for curd packaging to expel excess water from curd and maintain a cool surface through evaporative cooling, excessive porosity could drain too much of moisture through capillaries and adversely affect the texture of curd.

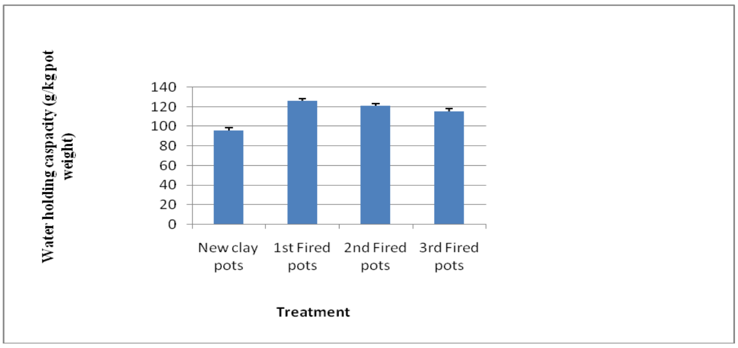

Figure 5: Water holding capacity of clay pots after re-firing (g of water/kg of pot)

3.4 Effect of re-firing on colour of pots

Colour of the clay pot depends on the type of clay used for manufacturing of pots. Clays contain predominantly alumina ($A1_2O_3$) and silica (SiO_2), iron oxide as an impurity in clays, which is the ingredient that determines their color. Earthenware clays contain a relatively high amount of iron oxide. When firing the clay pottery, brick red colour is developed depending on the availability of iron oxide in the clay (Conway, 1976).

According to the results, there is a significant difference in the colour of clay pots among different treatments. According to the table 1, there is a significant different between new pots and other pots in both dry and saturated conditions at p>0.05. Further, there is a significant difference between third re-fired pots to other pots under both dry and saturated conditions at p>0.05. Between first re-fired pots and second re-fired pots, colors are not significantly different at p>0.05. Colour of second re-fired pots to third fired pots under saturated condition is also not significantly different at p>0.05. Therefore, there is an effect of re-firing on the surface colour of the clay pots and this may be due to the completion of the oxidation reactions of ferrous available in pots. The increasing redness with re-firing gives an additional sales appeal for curd marketing.

Table 1. Mean separation of colour data (hue angle)

	New pot	***1st fired***	***2nd fired***	***3rd fired***
Dry pot	*0.8062*^{a}	*0.8041*^{b}	*0.8065*^{b}	*0.8169*^{c}
Saturated	*0.8184*^{a}	*0.8166*^{b}	*0.8409*^{bc}	*0.8248*^{c}

a=a, b=b, c=c – No significant difference, a≠b/c, b ≠a/c, c ≠ a/b – have significant difference

3.5 **Effect of re-firing on bacterial colony counts in pots before packaging**

Table 2 shows the mean colony counts of clay pots under different treatments. The highest number of mean colony counts was observed in the control while the least number of counts was observed in the 1st time fired pots. According to the mean seperatio, control (virgin clay pots) had significant difference at p>0.05 to all other tree treatments. It had the highest colony count among four treatments. The pots treated as 1st, 2nd, 3rd re-firing has no any significant difference at p>0.05 to each other. The reason may be due to high initial contamination of new pots during transportation and storage due to the use of paddy straw as a cushioning material in transportation in trucks. Pandithage (2008) has also reported similar results.

Table 2: Means of colony count of empty clay pots

Treatment	*Mean number of colony counts per pot*
Control (new clay pots)	*1583*
1st fired	*563*
2nd fired	576
3rd fired	679

3.6 Evaluation of the pH of curd under different treatments

Figure 6 shows the mean pH variation of curd packed in virgin and re-fired clay pots for a period of 12 days. The highest pH value was observed in the control (new clay pots) during the storage of 12day period while the least pH value was found in the third fired clay pots. The first and second fired pots showed a medium pH range in between the control and third fired pots. However, pH of first fired pots is higher than the pH of second fired pots.

There was a significant difference of pH among four different treatments at p>0.05. According to the mean separation, as shown in table 3, pH of new pots and 1st fired pots are not significantly different throughout the measurement period of 12 days. But there was significant difference between 1st fired and 2nd fired clay pots in 3rd day and 12th day observations, while 5th, 7th, 10th day pH values were not significantly different. The pH range of 3rd fired pots was significantly different from other three treatments throughout the period of measurement. The maximum permitted pH for curd is 4.5 by the Food (Standards) Regulations 1989 under Food Act, No. 26 of 1980 (Sri Lanka) and curd packed in all new pots, 1st and 2nd re-fired pots could be stored only for five days while in 3rd re-fired pots it is only up to 3 days.

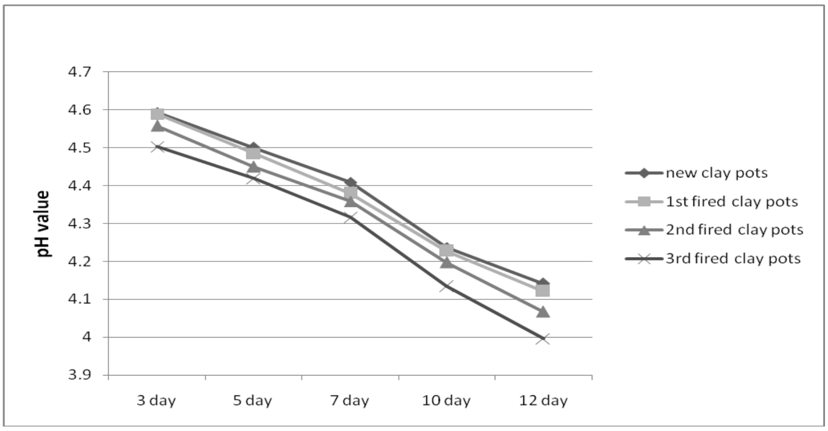

Figure 6: Variation of pH of curd under different treatments

Although curd is a fermented product and milk fermentation is done by specific group of microorganisms (Marshel and Tamime, 1984), unwanted microbial contaminations could reduce the pH of curd during storage below the accepted range. Although it was not significant, the water holding capacity has declined with increasing number of re-burning. That indicates some degree of reduction of capillaries of the pot with re-burning. This may be resulted in converting some micro pores into macro pores or micro cracks. If such a change has occurred, it could lead to open an entry path to microbes from the environment. Therefore, this phenomenon could be a reason for least pH of curd packed in 3rd re-fired clay pots. In addition, less shelf life due to reduced pH of all treatments after five days may also be due to high initial microbial counts of raw milk or in the culture media used for curdling.

Table 3: Mean separation of pH of curd

	New pots	***1st fired***	***2nd fired***	***3rd fired***
3 day	*4.5925*^{a}	*4.58875*^{a}	*4.5575*^{a}	*4.5025*^{c}
5 day	*4.5*^{a}	*4.485*^{ab}	*4.45*^{bc}	*4.41875*^{c}
7 day	*4.40875*^{a}	*4.38*^{ab}	*4.35875*^{b}	*4.31625*^{c}
10 day	*4.23625*^{a}	*4.2275*^{ab}	*4.1975*^{b}	*4.13375*^{c}
12 day	*4.14125*^{a}	*4.12125*^{a}	*4.0675*^{b}	*3.99625*^{c}

a=a, b=b, c=c – No significant difference, a ≠b/c, b ≠a/c, c ≠ a/b – have a significant difference

3.7 Shrinkage of curd

Shrinkage of curd was observed in third fired clay pots especially during the last few days of testing time. Recorded data are not available on shrinkage of curd and only observed that there was higher shrinkage and solidification of curd in the 3rd fired clay pots than others. The shrinkage may be due to increase of pores in the re-firing process than in new clay pots.

3.8 Mold growth on curd surface

There was no any observation of mold growth on curd surface during the period of twelve days of storage at 4^0C. Although, the pH was little below the standard value, the curd can be sold and consumed without a major health risk. Usually, the storage time period of curd is 12 days and should not be consumed after 13th day.

3.10 Pollution minimization through energy conservation

The poly propylene (PP) packaging material used for yoghurt cups consumes 81MJ/kg for raw material production, 0.5MJ/t.km for transport, 20MJ/kg for molding and 20MJ/kg for recycling (Bey, 2000). Whereas the clay pottery requires 0.05984MJ/kg for raw material and transport, 0.03547MJ/kg for clay preparation and 2.4805 MJ/kg for molding, 2.4242MJ/kg for firing and 0.0MJ/kg for recycling (dumping) (Boustead and Hancock, 1981 and Bey, 2000). Therefore, the total lifecycle energy requirements for PP and clay are 121MJ/kg and 5MJ/kg, respectively. However, the weight of a 1L plastic cup is about 50g while the clay pot is about 1kg. Therefore, the energy requirement for a cup is about 6.05MJ for PP and 5.0MJ per clay pot. However, through the re-burning process, a pot can be used three times and, it is possible to reduce one third of the energy requirement for a pot (1.7MJ/kg). This will lead to save the earth by minimizing the emissions to the environment due to burning of fossil fuels during the manufacture. According to literature, about one half of total energy of pot making is for firing and the other half is for all other manufacturing operations. Assuming that re-burning is mainly done at small sale sales centres with insignificant transport energy, One can estimate the total energy saving in pot manufacture in Sri Lanka as 85TJ per year by considering the annual curd production. In real terms it is about 1,843,902 L of Diesel or 6,500t of fire wood per year could be saved and hence emissions are reduced.

4. Conclusions and recommendation

Re-firing does not affect on compressive strength under dry or wet conditions and weight of pot but the initial microbial loads of pots were reduced while increasing the redness of the pot. The water holding capacity or the porosity of pots is increased due to re-firing. Re-firing affected significantly on the pH of curd especially after third firing. Therefore, used clay pots can be reused at least twice after proper re-firing at 800 ^{o}C for curd packaging without any quality deterioration of packed curd. The re-firing process saves 1/3rd of clay requirements for pot manufacture and 34% of total energy used in clay pot manufacture and thereby minimizing flu gas emissions leading to environment pollution.

References

Axtell, B. and Fellows, P. 1993. *Appropriate food packaging.* Tool publications, Amsterdam, Netherlands.

Bey, N. 2000. *The oil point method – A tool for indicative environmental evaluation in material and process selection.* PhD Thesis, ISBN 87-90855-09-4, Department of manufacturing engineering, Technical university of Denmark, Lynby, Denmark.

Boustead, I and Hancock, G. F. 1981. Energy requirements of a vitrified clay pipe drainage system. Resources and conservation, *Elsevier Scientific Publishing Company, Amsterdam. 6 (1981) 241-261.*

Conway, G. 1976. Pottery Reduction Firing with a Fuel-Burning Kiln. *Leonardo, Vol. 9, No. 2, 89-93. MIT Press. Available at* http://www.jstor.org/stable/1573113 (accessed on 10.08.2010)

Department of Census and Statistics. 2010. *Agriculture and Environment Statistics Division, Sri Lanka.* http://www.statistics.gov.lk/agriculture/Livestock/MilkProduction.html (accessed on 08.08.2010).

Food (Standards) Regulations 1989 under FOOD ACT, No. 26 of 1980, *Specification for fermented milk products,* part 1. Colombo, Sri Lanka.

Knox, R. and walker, J. 1947. Bacteriological investigation of the washing and sterilization of food containers. *The Journal of Hygiene 45(2): 151–158. (online)* www.ncbi.nlm.nih.gov/pmc/articles/PMC2234863/.../jhyg00183-0043.pdf

Marshel, V.M.E. and Tamime, A.Y. (1984). Microbiology and technology of fermented milks. (In) Microbiology and Biochemistry of Cheese and Fermented Milk. B.A. law (Ed). PP.57-133. *Blackie academic and professional, Chapman and hall, Madras.*

Pandithage, D.D.C. 2008. Testing and evaluation of Steam injection for cleaning and sterilization of new clay pots used for curd packaging. Department of Agricultural Engineering, Faculty of Agriculture. *(Unpublished final year student project report).*

The American Ceramic Society, 2005. *Pottery making illustrated. (online)* www.potterymaking.org (accessed on 07.05 2010).