EFFECT OF INDIGENOUS KNOWLEDGE SYSTEM BASED SUN DRYING ON THE MICROBIOLOGICAL QUALITY AND SAFETY OF EGG POWDERS

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ABSTRACT
Although eggs have been successfully dried into powder at industrial level no evidence is available that sun drying or oven drying has been tried on eggs in the rural areas. This article is based on the study, which was conducted in the rural areas of Impendle in the KwaZulu-Natal Province of South Africa, determined the level of egg utilisation and the microbiological quality and safety of sun-dried eggs. A sample of eggs was oven-dried at 65°C over a period of three hours. Another sample was sun-dried over a period of 72 hours. The dried egg samples were subjected to microbiological analysis: Salmonella spp., E. coli, Coliforms, Listeria monocytogenes and Total Plate Count. A high percentage (87%) of the survey respondents owned egg laying chickens. About 81% of the respondents indicated that eggs were consumed by the whole family about three times per week. Microbiological analysis results indicated that both egg powder samples had acceptable total microbial load and pathogenic (harmful) micro-organisms were absent. When observed over a period of eight weeks, both sun-dried and oven-dried eggs developed a rancid flavour. The study demonstrated the potential for processing eggs into egg powder in rural areas to improve household food security.

Keywords: Egg preservation, microbiological quality and safety, egg powder, food security.

INTRODUCTION
Chicken eggs are categorised as a complete food for the population which is below the poverty line and devoid of a nutritious diet (Luber, 2009); they are an important source of proteins and other nutrients (Cherian, 2008). In South Africa, as the case in other sub-Saharan African countries, most rural households produce chicken eggs and as such eggs probably play a prominent role in household food security. Unfortunately eggs are highly perishable and fragile. Poverty is prevalent among the rural households of sub-Sharan African countries, including South Africa. Most of these households cannot afford modern food storage and preservation technologies and hence a significant amount of their agricultural produce, especially the perishable type, like eggs, is lost both in quality and quantity through deterioration. Other factors, such as pests and predators and physical damage also contribute to produce loss. Limited access
to markets by the rural small-scale farmers also contributes to produce loss. According to Hendriks, Lyne and Chitja (2009), the South African small-scale farmers are challenged by limited access to markets due to infrastructure, supporting services and manipulation in the fresh egg markets by commercially well-established farmers and thus the small-scale farmers lose some of their eggs to spoilage and/or breakage.

In sub-Saharan African rural areas, many types of foods are eaten fresh, dried or in other processed forms. Fresh foods are normally eaten soon after harvest, but some of the fresh foods can be preserved using traditional preservation methods, such as fermentation, drying and pickling (Ibnouf, 2013). Leafy vegetables, fruits, meats and corn, among other crops, are eaten fresh in rural areas during their ripening season (Hart, 2011). Towards the end of the ripening season, they are harvested and dried traditionally by sun drying methods for consumption in future. Traditionally dried foods have been considered safe and nutritious for the rural households.

Preservation of food by sun drying has several advantages. The dried food has a long shelf life; the food requires less storage space; there are minimal nutritional losses; and sun drying is considered one of the least expensive preservation methods (Samad et al., 2009). Direct sun drying practised in rural areas also has some disadvantages. It depends on the weather conditions; during winter and rain seasons, it is difficult to practise as the food takes longer to dry. In summer, the temperatures are high and the humid environment causes a prolonged drying process or causes food deterioration (Hart, 2011). Sun drying also requires sizeable exposure areas if air circulation is to reach all parts of food items being dried. Sun-dried products are susceptible to microbial contamination by the action of insects, rodents or other small animals (Guiné et al., 2007). In a survey done in Zambia, Nguni and Mwila (2007) it was found that most rural consumers who practised direct sun drying complained of product deterioration due to rain, wind, moisture and dust; and loss of produce due to animals. In another study, consumers complained that the sun-drying process is labour intensive, time consuming and required a large surface area to spread the produce out (Tunde-Akintunde, 2010).

Whereas drying has been employed traditionally in most food products in rural areas, it seems it has not been tried on eggs. Eggs in rural communities are eaten fresh in the form of boiled, scrambled and fried, or in baked products. A high proportion of the eggs not eaten immediately after hatching are lost through deterioration and/or breakage. This reduces the nutrition and food security of the rural communities and hence there is a need to try innovative egg preservation methods, such as sun drying.

**RESEARCH METHODOLOGY**

**Study area**

The survey was carried out in the rural areas of Impendle in KwaZulu-Natal Province of South Africa. Impendle is located within the western portion of.
Umgungundlovu District Municipality, situated in the west of KwaZulu-Natal Province. The current population of Impendle municipality is about 35,000 people.

Survey

A survey was conducted in three villages, namely, Gomane, eSwampu and Nguge in Impendle. A questionnaire written in Zulu was administered to 120 respondents to inquire about egg utilisation. This was done with the assistance of two trained field workers who assisted the respondents individually in filling out the questionnaire. The questionnaire had several questions, including those that inquired about ownership of egg laying chickens and egg consumption/utilisation.

Drying of eggs

For this study, oven drying and sun drying were used. Sun drying was used because it is one of the simplest methods used for drying other forms of food in rural areas. Oven drying was also used because the peri-urban households have access to electricity and hence could explore oven drying. Large sized eggs (50g) were broken and whisked in a porcelain bowl. From the whisked portion, 100g of whisked egg was spread in a 15cm x 25cm glass tray, covered with cotton voile and put on an elevated position where there was unhindered insolation and where there was free air circulation. The eggs were left to dry until they had a crispy feel for 72 hours. The dried eggs were spread on a cutting board and crushed into powder using a wooden roller.

Large sized eggs (50g) were broken and whisked in a porcelain bowl. A portion of whisked eggs (100g) was spread in a 15cm x 25cm glass tray. The product was put in an oven at 50°C for three hours until it had a crispy texture. The dried eggs were spread on a cutting board and crushed into powder using a wooden roller. The dried egg samples (both oven- and sun-dried) were kept in tightly sealed containers and observed weekly for any visible physical deterioration for eight weeks.

Microbiological quality and safety analysis of dried eggs

Total Plate Count, Coliforms, E. coli and Samonella were determined according to SABS ISO standards methods, which are briefly described below.

Preparation of serial dilutions: The method followed for preparation of serial dilutions was the same for all bacterial analyses. Accurately, 25g of egg samples were transferred into 250ml of distilled water. The samples were thoroughly mixed on a platform shaker. Exactly 1ml aliquots of the samples were drawn using separate sterile pipettes into test tubes containing 0.9% of saline water. Serial dilutions were prepared from this up to 10⁻⁴. The diluted samples were shaken thoroughly before plating.

Total plate count: Total plate count was done following the SABS method, (SABS ISO 4833: 1991). Exactly 0.1ml of each of the serially diluted samples
was pipetted into separate, duplicate, appropriately marked petri dishes. Twelve
to fifteen millilitres of plate count agar were added (cooled to 45 ± 1°C) to each
plate within 15 minutes of the original dilution. Sample dilutions and agar medi-
rum were mixed thoroughly and uniformly by alternate rotation and back-and-forth
motion of plates on flat level surface and left to solidify. The plates were incubat-
ed promptly for 48 ± 2h at 35°C (Anon, 1991a).

**Total Coliform count:** Total Coliforms and the presence of E. coli were deter-
mined following the SABS method, (SABS ISO 4832: 1991). The diluted samples
(described above) were plated by the pour-plate method, in duplicate, using
violet-red bile agar (VRB) and incubated at 37°C for 24 hours. E. coli was differ-
entiated from other coliforms using standard microbiological tests. A positive
indole test and the presence of short Gram-negative rods was taken as positive
for the presence of E. Coli (Anon, 1991b).

**Presence of Salmonella spp:** The presence of Salmonella spp. was analysed
following the ISO method (ISO 6579: 2002). The pre-enrichment was carried out
by adding 25g egg samples to 225ml buffered peptone water (Difco, East
Molesy, UK/Merck, Amsterdam; the Netherlands) followed by incubation at 37°C
for 18 ± 2h. From the pre-enrichment culture, 1ml was inoculated in 9ml RV
broth (Oxoid, Haarlem; the Netherlands). After an incubation of 24 ± 1h at 42°C
the RV culture was streaked onto brillian green agar (BGA; Oxoid). If suspect
colonies were not found on BGA after incubation, the RV culture was again
streaked onto BGA after a second incubation period of 24 ± 1h at 42°C (Anon,
1993).

**Presence of L. monocytogenes:** Serial dilutions for each homogenised egg
sample was made in 0.9% saline water up to 10⁻¹. To determine L. monocytogen-
es the method of Taormina and Beuchat (2001) was followed, which involved
surface plating on Listeria selective agar (PALCAM, Oxoid, Basingstoke, UK)
with modified Listeria selective supplement (Oxoid). Typical colonies were
selected and counted after incubation at 37°C for 24h.

**Other quality analyses**

**Determination of moisture content:** The moisture content was determined by
measuring the mass of an egg sample before and after the water had been
removed by evaporation. The moisture content was calculated as follows:

\[
\%\text{Moisture} = \frac{M_{\text{FINAL}} - M_{\text{DRY}}}{M_{\text{INITIAL}}} \times 100
\]

**Determination of colour variation and odours:** The dried eggs were monitored for
colour changes and development of unusual odours. Every week, a small portion
of each egg powder sample was taken and compared with the other egg powder
and also with commercial egg powder. Approximately 10g of oven dried, sun-
dried and commercial egg powder were each placed, separately, in a white plate
and hipped. The researcher then visually analysed the samples for colour
changes. The changes in the smell of the eggs were monitored by placing 10g of
each egg powder sample in a measuring cylinder and the presence of pungent
smells or odours examined by the researcher using her sense of smell.

STATISTICAL ANALYSIS
Means of duplicate plates were calculated using IBM SPSS 21.

RESULTS AND DISCUSSION
Demographics of survey respondents
A total of 120 respondents were interviewed, of which 54% were female and
46% were male. Forty nine percent of the interviewees were aged 40 years and
above. The youth (16-25 years) and the adults (26-40 years) constituted 26%
and 25%, respectively. Figure 1 summarises the demographics of the sampled
households (respondents).

Figure 1: Demographics of sampled households.
The demographics also showed that 53% of the respondents were single, whilst 30% were married. The demographics show that there was more or less equal gender distribution. The majority of the respondents were aged 40 years and above. Most of the study participants had primary and secondary school education and few had tertiary education.

**Egg utilisation in Impendle**

A high proportion (87%) of the survey respondents reported that they owned egg-laying chickens. About 81% of the respondents indicated that eggs were consumed by the whole family, whilst 3.2% to 5.5% of the respondents indicated that they did not eat eggs due to unstated reasons. Each household’s food basket contained eggs for nutrition benefit and their contribution towards a diversified diet. To further maintain this statement most households consumed eggs about three times a week. Eggs formed main part of meals, consumed as relish (animal protein) complementing staple foods such as rice and maize-based dishes. Previous studies indicate that egg consumption patterns are not uniform across countries. Studies conducted in Zimbabwe revealed that egg consumption was low and similar across seasons, regardless of the availability of eggs (Muchadeyi et al., 2005). In other areas of Ethiopia eggs were consumed for luxury, religious and medical reasons, whilst 2.2% of the study participants reported to not have eaten eggs (Moges et al., 2010a). In Impendle, eggs were more frequently consumed relative to other rural areas of other countries in Africa studied.

However, it should be mentioned that the respondents were consuming commercial eggs rather than eggs from their own flocks due to a number of challenges faced in egg production and storage among Impendle rural households. According to the study respondents (48%), egg deterioration was the main challenge followed by losses due to predators, such as dogs, cats and wild birds. The limited knowledge of egg storage and preservation methods compromises the food security status of households as they purchase eggs instead of using eggs from their own flocks.

**Microbiological quality and safety of the dried eggs**

Table 1 shows that the total plate counts of the egg powders were more than that of the fresh egg (control), but less than that of the standard. Total coliforms in the egg powders were less than the standard. There were no growths observed for L. monocytogenes, E. coli, and Salmonella spp.
Table 1: Bacterial counts for fresh egg, oven dried egg and sun-dried eggs (cfu/g).

<table>
<thead>
<tr>
<th>Test</th>
<th>Oven-dried</th>
<th>Fresh egg</th>
<th>Sun-dried</th>
<th>Water</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Plate Count</td>
<td>1.55 x 10^3</td>
<td>1.28 x 10^2</td>
<td>5 x 10^3</td>
<td>Nil</td>
<td>&lt;20000 cfu/g</td>
</tr>
<tr>
<td>Total Coliforms</td>
<td>&lt; 10</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>Nil</td>
<td>&lt; 50 cfu/g</td>
</tr>
<tr>
<td>E. coli</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>Nil</td>
<td>0</td>
</tr>
<tr>
<td>Salmonella</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>Nil</td>
<td>0</td>
</tr>
<tr>
<td>Listeria monocytogenes</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>Nil</td>
<td>0</td>
</tr>
</tbody>
</table>

ND = Not detected (<) is less than

The total plate count of a food samples is indicative of its total microbial load and hence the general microbiological quality of the food (Annon, 2001). The microbial loads of the egg powders were acceptable as they were less than the standard (Table 1) and were not exceeding the standards reflected in the South African regulation as shown in the table. Total coliforms are used as a specific indicator of the microbiological quality of the food and the hygienic conditions under which it was processed. The results of this study indicate that the egg powders were of acceptable microbiological quality, because their total coliform counts were below the standard. L. monocytogenes and Salmonella spp., and certain E. coli strains are pathogenic to humans; food safety standards require that they be absent from food (Annon, 2001). The results (Table 1) of the counts (0) of these bacterial species indicate that the egg powders were microbiologically safe with respect to the pathogenic micro-organisms analysed for. There is, however, a need to analyse for other microbial pathogens, include food-borne pathogenic fungi. However, the total bacterial counts were the highest in sun-dried eggs. Figures 2 to 4 shows representative plates for the microbiological analysis (total plate count only). These results confirm the challenges of sun drying as documented in the literature (Bal et al., 2011, Guiné et al., 2007, Nguni and Mwila, 2007). The environmental factors, such as temperature and air circulation are not controlled during the sun drying of food. On the other hand, people in rural areas have been traditionally using sun drying to preserve vegetables, fruits and meat. If improved, sun drying can also be used effectively for egg drying.

Figure 2: Total Plate Count Fresh egg 10^-1 dilutions.

Figure 3: Total Plate Count sun-dried eggs 10^-1 dilution
Other quality attributes of dried eggs

**Moisture content:** Eggs were successfully dried to a moisture content of 5.3% for sun-dried eggs and 3.9% for oven-dried eggs. Studies have shown that the rate of egg powder deterioration increases with the increase in the moisture content (Koç et al., 2012, Koç et al., 2011a, Koç et al., 2011b, Koc et al., 2011). To maintain quality during storage and transport, dried egg should contain no more than 5% moisture and preferably 2% or less (Koc et al., 2011). High moisture content also promotes growth of micro-organisms which would accelerate deterioration.

**Odours:** At day 16 the egg powders developed an unpleasant odour that is not associated with fresh eggs. This observation is similar to that reported by Rannou et al. (2013). Other researchers have attributed the development of odour and off flavours to rancidity. Rancidity is one of the major causes of food deterioration. It is caused by oxidative and/or hydrolytic deterioration of lipids in foods (Viuda-Martos et al., 2010). In this study hydrolytic deterioration may have occurred due to the action of microbial enzymes since micro-organisms were detected in the egg powders. Rancidity due to oxidation is highly likely to have been the main cause of rancidity of the egg powders. Studies show that egg yolk lipids are oxidised during storage and the oxidation is influenced by storage time and temperature and the degree of unsaturation of the yolk fatty acids (Rocha et al., 2010). In another study Bonazzi and Dumoulin (2011) mentioned that lipid oxidation is responsible for rancidity, development of off-flavours, and the loss of fat-soluble vitamins and pigments in dehydrated foods.

According to Perera (2005), lipid oxidation is initiated by heat, light or free radicals and peroxides, activated by metal ions, and enhanced at higher dehydration temperatures. Moisture content also plays an important role in the rate of oxidation. At high moisture contents, lipids can undergo enzymatic hydrolysis, which may cause off-flavour formation, such as soapy tastes, depending on the type of lipids; at a low water activity of $a_w<0.2$, auto-oxidation of unsaturated fatty acids causes off-flavours such as rancidity. The porosity of the dried product can have an impact on oxygen concentration and affect the susceptibility to oxygen, which is, for example, higher for freeze-dried products. Broncano et al. (2009) found that high temperature treatment was responsible for oxidative rancidity. For sun drying and oven drying to work effectively in rural areas, methods for preventing the rancidity of the eggs should be developed.

**Colour of dried eggs:** The colour of oven-dried and sun-dried egg powders varied significantly from the commercial egg powder. However, no colour differences were noted between sun-dried and oven dried eggs.

Colour differences could be attributed to pre-treatment steps taken to commercial egg powder and treatment temperatures (Ndife et al., 2010). The colour of
egg powders plays an important role if the powder is to be used as a colouring agent in baking industries. The colour of dried egg powder can be maintained by preventing mouldiness and lump formation that are due to an increase in the moisture content of the product. The colour of oven dried egg powders may also be controlled by drying the eggs at temperatures that do not have a detrimental effect on colour. The colour of egg powder affects consumer acceptance of the product. However, colour variations are not an issue in the rural areas, as the egg powder resembles the traditional Zulu egg (Mnyandu, 2012).

CONCLUSION
The results of this investigation indicate that sun drying and oven drying could be used to preserve eggs in rural areas. Due to its much lower moisture content, the egg powder so produced would have a longer shelf life compared to fresh eggs. If practised hygienically, in a home setting, the egg powder produced using these methods would be microbiologically safe for human consumption. To prevent oxidative deterioration suspected in the egg powders of this study, proper storage methods can be practised. The investigation demonstrates a potential for the preservation of eggs by sun- or oven-drying them into egg powder in rural areas to contribute to food security. However, if not carefully practised, sun drying or oven drying can result in high microbial loads, including microbial pathogens, such as the deadly bacterium Salmonella, which commonly contaminates poultry products. It is paramount to train the rural community on safe and hygienic processing of eggs before the sun drying method is adopted. Further research can be conducted to find out how to reduce rancidity in sun-dried eggs.
REFERENCES


