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Microbiological quality of selected dried fruits and vegetables in Maseru, Lesotho

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Food safety is a global issue, affecting food production and processing. The study assessed the microbiological quality of commercially dried fruits and home dried fruits and vegetables in Lesotho. Moisture content, pH and water activity of the fruits and vegetables were determined using standard methods. Nine different growth media were used for microbial evaluation. Moisture content and water activity were within World Health Organisation guidelines for dried fruits and vegetables. Fungi counts ranged from 2.0×10^2 to 8.7×10^5 CFU g^{-1}, and dried pumpkin leaves recorded the highest. More than 45% and 38% of the samples exceeded the fungal and total aerobic counts recommended by WHO, respectively. Possible pathogens of the genera *Salmonella*, *Shigella*, *Bacillus* and other Enterobacteriaceae were isolated from home dried samples. Faecal coliforms were detected in 55% of the home dried food products. More than 60% of the samples recorded higher microbial levels than recommended. While half of commercially dried fruits exceeded international standards, all home dried fruits and vegetables recorded unacceptably high levels of fungal contamination. The presence of possible pathogenic organisms in these foodstuffs suggest a potential public health hazard to consumers. Sanitation and personal hygiene, especially during home-based food processing, needs improvement.

Key words: Dried fruits, food-borne illness; food safety, guideline, low moisture foods, microbial quality, vegetables

INTRODUCTION

Despite foods being an important source of nutrients to consumers, it serves as an excellent medium for microbial growth, some of which are pathogenic. Food safety is a global issue, affecting food production and processing.

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Food-borne illnesses are reported to be a major international problem and continue to be a public health concern, especially in developing countries where food standards, regulations and safety policies are not well established or are seldom in place (De Sousa, 2008; Food Safety Programme, 2002; Mensah et al., 2002). Despite the health risk and widespread concern of food-borne infections, only a fraction of them are diagnosed and reported, or can be traced to a definite source (Lukinmaa et al., 2004).

Fruits and vegetables are an important part of a healthy and balanced diet in all societies around the globe. They are known to carry natural non-pathogenic epiphytic microbiota but can be contaminated with pathogens from human, animal or environmental sources during growth, harvest, transportation, processing and handling (Beuchat, 2002; Olsen et al., 2000). While the prevalence of food-borne pathogens on dried fruits and vegetables and their involvement in food-borne outbreaks are not well documented, fresh fruits have been implicated in a number of documented outbreaks of food-borne illnesses particularly in Europe, Japan, United States and Canada (ECSCF, 2002; Erickson and Doyle, 2012). The major causes of the illnesses in the outbreaks were bacteria, viruses and parasites.

Drying is one of the oldest and most common methods of processing and preserving food. Home food drying remains popular as an alternative to canning (Wilhelm et al., 2004) in developing countries such as Lesotho, where cooling and suitable storage facilities are scarce. Fresh fruits and vegetables are highly perishable due to their high water content of about 80% (Kaleta et al., 2013; Karam et al., 2016). Drying fruits and vegetables does not only inhibit the growth of spoilage microorganisms, but also halts the occurrence of browning and other moisture-driven deterioration reactions and thus, preserving the structure, characteristics and nutritional value of the original material (Karam et al., 2016). The drying of fruits and vegetables, more importantly, minimises losses, enhances storage stability, reduces packaging and handling requirements, and makes transportation easier and cheaper because of reduced weight and volume (Kaleta et al., 2013; Karam et al., 2016). However, traditional sun drying is often a slow process and this increases the chances of microbial contamination (Karam et al., 2016).

Foods, such as fruits and vegetables, are sliced to increase surface-area to volume ratio for the loss of moisture during drying. Slicing is often done in the open with bare hands using a knife. The pieces are then dried in the open on the sun where they can come in contact with microorganisms, dirt, soil and insects and this subjects the products to possible microbial contamination. The food slices are left in full sun for some days until they have lost much of the moisture. Furthermore, some of the dried food products, especially fruits, are often consumed without any further processing steps such as cooking. Over and above these factors, proper hygienic practices are often limited in most rural areas of developing countries (Vivas et al., 2010). Furthermore, the difficulty in significantly reducing microbial hazard contamination of dried foods by traditional processing methods such as heating has been reported (Beuchat et al., 2013; Finn et al., 2013). On the contrary, commercial drying of fruits is done in protected environments and often, under more hygienic conditions.

Dried fruits and vegetables form one of the seven categories of low moisture foods (LMF) that were assessed by the Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO), following concerns raised on their microbial quality (FAO/WHO, 2014). The FAO/WHO (2014) define low moisture foods (LMF) as foods that are naturally low in moisture content or are produced from higher moisture foods through drying or dehydration processes. The low water activity (a_w) of these foods prolongs their shelf life and, has for many years, promoted the perception that these foods are microbiologically safe (FAO/WHO, 2014; Finn et al., 2013).

Given that drying of fruits and vegetables prohibits microbial growth, very little attention has been given to the safety of home dried foods until recently. Nevertheless, notwithstanding the fact that micro-organisms cannot grow in these LMF, recent outbreaks of foodborne illnesses linked to these food products have demonstrated that pathogenic microorganisms in LMF can persist for long periods of time even under conditions of low a_w (Beuchat, 2002; Beuchat et al., 2013; FAO/WHO, 2014; Finn et al., 2013; Prescott et al., 2001). These micro-organisms have the potential to cause illness due to their low infectious dose or possible subsequent favourable temperature that allows the organism to grow (Beuchat et al., 2013; Finn et al., 2013).

Generally, growth of bacteria and fungi is confined to water activity (a_w) levels above 0.90 (Lund et al., 2000). Lund et al. (2000) observe that pathogenic bacteria grow best at a_w levels of at least 0.98, which is the range in which fresh fruits and vegetables are found. Unlike bacteria that cannot grow below 0.85 a_w, fungi are more tolerant to reduced a_w and can grow even below 0.80 (Lund et al., 2000; Sagar and Suresh, 2010). While, the lowest a_w at which growth of bacteria has been reported was 0.75, fungal growth has been recorded at a_w levels as low as 0.61 (Lund et al., 2000).

Leistner (1992) report that moisture content and water activity (a_w) of artificially dried fruits and vegetables range from 15 to 50% and 0.60 to 0.89, respectively. These conditions can only cause dormancy in bacteria and fungi until a favourable environment is attained (Prescott et al., 2001; Sagar and Suresh, 2010). Microbial counts and pathogens higher than international stipulated limits (10^3 CFUg^{-1} for fungi and 10^1 CFUg^{-1} for bacteria) in both commercially and conventionally produced fresh, and

Table 1. Type and number of samples collected for commercially fruits and home dried fruits and vegetables.

Commercially dried	Number of samples	Home dried	Number of samples
Peeled peaches	20	Peeled peaches	20
Mangoes	20	Unpeeled peaches	20
Prunes	20	Apples	20
Pears	20	Spinach	15
Apricots	20	Traditional vegetable (*Wahlenbergia androsacea)*	15
Raisings	23	Pumpkin leaves	15
Dates	20	-	–
Guavas	21	-	–
Total	**164**		**105**

dried fruits and vegetables have been reported (Barkai-Golan and Paster, 2011; Johannessen et al., 2002; Mensah et al., 2002; Witthuhn et al., 2005). Pathogenic strains of *Salmonella* and *Escherichia coli* have been isolated from home dried food products (Beuchat et al., 2013; Finn et al., 2013). Studies in South Africa on the microbiological content of high moisture dried fruits showed the presence of pathogenic species such as *Salmonella*, *Staphylococcus*, *Clostridium* and high levels of fungi (Unicomb et al., 2005; Witthuhn et al., 2005).

Extensive scientific progress and technological developments in food processing has been achieved in the past few decades. Nonetheless, food safety problems remain a global challenge and may actually increase in future due to increase in food demand and the associated production. In response to the increasing number of food-borne illnesses, governments all over the world are intensifying their efforts to improve food safety (Thyagarajan and Ashok, 2014).

While the consumption of dried food products and their risk to human health increased globally, concerns have been raised on the microbial quality of the products (FAO/WHO, 2014). There has also been global recognition of the need to consider and manage the microbiological hazards associated with these products. A review on the prevalence of pathogenic microbial contamination (>10^3 CFU g^{-1}) in dried fruits and vegetables reported a global prevalence of about 4.84% (FAO/WHO, 2014). Subsequently, several regulatory authorities worldwide have developed recommendations and guidelines to prevent and manage potential risks of this product contamination from microbial hazards.

Conventional home drying of fruits and vegetables is practised in Lesotho where home drying processing of food is done under poor hygienic practices due to lack of education and awareness and, to a greater extent, lack of food safety polices and legislation. Despite home drying being common for food preservation in the country, the quality of home dried food is not monitored. In addition, Lesotho has limited capacity to effectively monitor food manufacturers and suppliers to ensure the bacteriological and chemical safety of the food as well as quality assurance (WHO, 2009). This, coupled with poor hygienic practices, creates high potential risk of microbial contamination and possible transmission of pathogenic microorganisms to humans. However, Lesotho imports most, if not all of its commercially dried fruits (high moisture dried fruits) and vegetables. The speculation that the presence of pathogens in dried fruits and vegetables in the markets in the country is prevalent has not been investigated. The main aim of this study was to assess the microbial quality and safety of commercially dried fruits and home dried fruits and vegetables sold in supermarkets and informal markets around the city of Maseru, Lesotho.

MATERIALS AND METHODS

The study was conducted in the city of Maseru. Commercially dried fruits (within the best-before-date) were bought from supermarkets and home dried fruits and vegetables were bought from the informal market around the city. Random sampling was used to collect samples for four weeks in February 2014. Samples were collected under normal purchase conditions and immediately packaged in sterile polythene bags that were sealed and transported to the laboratory in cooler boxes containing ice packs where they were analysed immediately or stored at 4°C until analysis. Table 1 presents the type of fruits and vegetables, and number of samples collected for each type of product. All analyses were done within 48 h of sample collection.

Moisture content (%) and pH of the samples were determined using a HANNA, HI 8314 membrane pH meter according to methods described in 923.03 of AOAC International (AOAC, 2000). Water activity (a_w) for the samples was measured using a labMaster - a_w instrument (USA) at 25ºC ± 2ºC as described by Witthuhn et al. (2005). Microorganisms were enumerated and isolated using nine different selective media that are presented in Table 2. The sample (20 g) was suspended in 80 ml of sterile 0.1% peptone water (Oxoid CM009) and homogenized for 2 min using a stomacher blender (lab-blander 400) in a sterile stomacher bag. Further serial dilutions (10^{-1} to 10^{-5}) were prepared and plated in triplicate onto each specific medium. Aliquots, 0.1 ml and 1 ml, of each dilution were used for spread plating and pour plating respectively, into the various media (APHA, 2001). Furthermore, the methods used by Ntuli et al. (2013) and Witthuhn et al. (2005) were adopted and followed for the enumeration and isolation of bacteria and fungi in this study.

Table 2. Methods for the enumeration and isolation of microorganisms in fruits and vegetables.

Media	Organism	Temperature and time of incubation
Potato dextrose agar (PDA)	Fungi	25°C for five days
Plate count agar (PCA)	Total aerobic counts	37°C for 24 h
Violet red bile agar (VRBA)	Total coliform	37°C for 24 h
Faecal coliform agar (FCA)	Faecal coliforms	44°C for 48 h
Eosin methylene blue agar (EMBA)	*E. coli*	37°C for 24 h
Reinforced clostridial agar (RCA)	*Clostridium* spp.	37°C for 24 h
Bacillus cereus agar (BCA)	*Bacillus* spp.	37°C for 48 h
Brilliant green agar (BGA)	*Salmonella* spp.	37°C for 24 h
Salmonella –Shigella agar (SSA)	*Salmonella* and *Shigella* spp.	37°C for 24 h

All media used were from Merck South Africa. Method was adopted from Witthuhn et al. (13).

Table 3. Physico-chemical parameters (mean ± SE) of commercially dried and home dried fruits and vegetables (n=280). SE=standard error.

Parameters	Sample	pH	Moisture (%)	A_w
Commercially dried	Peeled peaches	3.81±0.11	17.41±0.21	0.81±0.07
	Mango	4.00±0.01	29.90±5.90	0.82±0.04
	Prunes	3.82±0.02	24.64±0.70	0.83±0.03
	Pears	3.41±0.02	23.41±0.28	0.82±0.11
	Apricot	3.37±0.68	21.85±0.14	0.79±0.04
	Raisings	3.85±0.04	15.78±0.21	0.78±0.05
	Dates	4.63±0.02	21.25±0.70	0.82±0.15
	Guavas	4.37±0.04	12.95±0.84	0.83±0.03
Home dried	Peeled peaches	4.53±0.02	19.0±0.02	0.82±0.13
	Unpeeled peaches	4.12±0.01	20.0±0.01	0.84±0.01
	Apples	4.03±0.10	19.85±0.10	0.83±0.02
	Spinach	6.69±0.04	8.75±0.04	0.78±0.03
	Traditional vegetable	6.74±0.01	7.35±0.01	0.79±0.02
	Pumpkin leaves	8.27±0.40	8.05±0.040	0.71±0.01

Triplicate determinations were carried out and standard errors were calculated for all microbial counts. All data collected were analyzed using one way analysis of variance (ANOVA) to determine significant differences ($p < 0.05$) among the means. All statistical tests were carried out using the SPSS for Windows Version 16.0 package by SPSS Inc., USA.

RESULTS

The physico-chemical characteristics of commercially dried fruits and home dried fruits and vegetables are presented in Table 3. Moisture content (%) and pH differed significantly ($P<0.05$) among the samples. However, there was no significant difference in the water activity of the samples.

The moisture content (%), pH and a_w ranged from 12.95±0.84 to 29.90±5.90, 3.37±0.68 to 4.63±0.02 and 0.78±0.05 to 0.83±0.03, respectively for the commercially dried samples and from 7.35±0.01 to 20.0±0.01, 4.03±0.10 to 8.27±0.40 and 0.71±0.01 to 0.84±0.01, respectively for the home dried samples. Albeit home dried vegetables recording low moisture content, they had high pH values with the highest, 8.27±0.40, recorded in pumpkin leaves. Unpeeled peaches recorded the highest a_w value (0.84±0.01).

Table 4 presents the microbial content (mean ± SE) of the commercially dried fruits and home dried fruits and vegetables. Commercially dried fruits contained fungi and viable aerobic bacteria only. Fungi counts for commercially dried fruits ranged between $2.0 \times 10^2 \pm 32$ and $6.3 \times 10^3 \pm 90$ CFU g^{-1}, while total viable (PCA) counts ranged from $5.4 \times 10^1 \pm 0.6$ to $1.0 \times 10^3 \pm 100$ CFU g^{-1}. Commercially dried guavas recorded the highest fungi counts ($6.3 \times 10^3 \pm 90$ CFU g^{-1}) while mangoes had the highest total viable counts (PCA) of $1.0 \times 10^3 \pm 100$ CFU g^{-1}. Similarly, Table 4 indicates that *Bacillus spp.* was present only in home dried peeled peaches (2.0×10^1 CFU g^{-1}) and apples (4.5×10^1 CFU g^{-1}). The home dried peeled

Table 4. Microbial content (mean ± SE) (CFU g^{-1}) of different commercially dried fruits and home dried fruits and vegetables.

	Sample	PDA	PCA	VRBA	FCA	EMBA	RCA	BCA	BGA	SSA
Commercially dried	Peeled peaches	2.6×10^{2} ± 10	2.4 x 10^{2}± 15	0	0	0	0	0	0	0
	Mangoes	4.2 x 10^{3}± 69	1.0 x 10^{3}± 100	0	0	0	0	0	0	0
	Prunes	3.8 x 10^{3}± 89	54± 6	0	0	0	0	0	0	0
	Pears	2.0 x 10^{2}± 32	2.0 x 10^{2}± 85	0	0	0	0	0	0	0
	Apricots	7.2 x 10^{2} ± 88	59± 4	0	0	0	0	0	0	0
	Raisins	1.0 x 10^{3}± 20	2.6 x 10^{2}± 7	0	0	0	0	0	0	0
	Dates	4.6 x 10^{3}± 10	79± 0.89	0	0	0	0	0	0	0
	Guavas	6.3 x 10^{3}± 90	1.3 x 10^{2}± 5	0	0	0	0	0	0	0
Home dried	Peeled peaches	4.0 x 10^{2}± 18	3.0 x 10^{2}± 17	0	0	0	0	2.0 x10^{1}±1	0	0
	Unpeeled peaches	3.1 x 10^{3}± 104	1.0 x 10^{3}± 60	0	0	0	0	0	0	0
	Apples	3.9 x 10^{2}± 8	2.0 x 10^{2}± 10	0	0	0	0	4.5 x10^{1}±2	0	0
	Spinach	6.5 x 10^{5}± 1000	9.2 x 10^{5}± 896	5.6 x 10^{6}± 100	8.9x10^{1}±3	9.0 x10^{1}± 6	0	6.1 x10^{1}±3	0	0
	W. androsacea	9.4 x 10^{5}± 667	5.4 x 10^{6}± 1100	3.5 x 10^{6}± 350	6.5 x10^{1}	3.2 x 10^{2}	0	5.6 x10^{1}±2	10±1	0
	Pumpkin leaves	8.7 x10^{5}± 200	6.7 x 10^{6}± 790	7.7 x 10^{7}±2980	4.0 x 10^{4}± 500	2.9 x 10^{2}± 40	0	5.7 x10^{1}±2.5	3.0x10^{1}±2	6±0.1

Traditional vegetable = *Wahlenbergia androsacea*.

peaches recorded higher counts for fungi (4.0×10^{2} ± 10 CFU g^{-1}) than commercially dried peeled peaches (2.6×10^{2} ± 10 CFU g^{-1}).

There was no *E. coli* and coliforms in home dried fruits. However, very high levels of coliforms (5.6x10^{6}±100, 3.5x10^{6}± 350, 7.7x10^{7}± 2980) and faecal coliforms (8.9x10^{1}±3, 6.5x10^{1}, 4.0x10^{4}±500) were found in dried spinach, traditional vegetable (*Wahlenbergia androsacea*) and pumpkin leaves, respectively. More than 45% and 38% of commercially and home dried samples were above the World Health Organisation (Food Safety Programme, 2002) recommended limits in terms of fungi counts and total aerobic counts, respectively.

Possible pathogens of the genus *Salmonella*, *Shigella*, *Bacillus* and other Enterobacteriaceae were isolated from home dried samples. However, the pathogenicity of the organisms was not confirmed in this study. Faecal coliforms were detected in 55% of the home dried fruits and vegetables. *Bacillus spp.* were isolated in home dried peeled peaches, apples, spinach, traditional vegetable and pumpkin leaves and the counts were 2.0x10^{1}, 4.5x10^{1}, 6.1x10^{1}, 5.6x10^{1} and 5.7x10^{1} CFU g^{-1}, respectively.

DISCUSSION

Water activity levels and pH values for dried raisins, peaches, apricots and prunes were comparable to those recorded by Witthuhn et al. (2005) in South Africa. However, the current study recorded much lower levels of moisture than those found in South Africa. Moisture content and water activity of dried fruits and vegetables met the WHO guidelines. Microorganisms present in dried fruits and vegetables are directly related to the water used and the hygienic conditions practised during their cultivation, harvesting, post-harvest handling, processing and distribution of the produce (Beuchat, 1996; Halablab et al., 2011). Consequently, these microorganisms on fruits and vegetables may act as a reservoir which may be responsible for further post-harvest contamination, if not reduced or eliminated (Barth et al., 2010; Joint FAO/WHO Codex Alimentarius Commission, 1994).

Results presented in Table 4 are in line with the guidelines by Gilbert et al. (2000). According to Gilbert et al. (2000), total aerobic count (TAC) of $<10^{2}$ CFU g^{-1}, total coliform (TC) $<10^{4}$ CFU g^{-1} and faecal coliform (FC) counts of $<10^{2}$ CFU g^{-1} are acceptable. Accordingly, the bacteriological quality (CFU g^{-1}) based on total aerobic count (TAC), TC and FC for all commercially dried selected produce were within acceptable levels. For commercially dried fruits, TAC values were ranging from $5.4x10^1$ to $1x10^3$ CFU g^{-1} and no TC and FC counts were detected on VRBA and FCA. More importantly, TAC and FC are real indicator organisms (that is, for hygiene and sanitary conditions) and for this reason their presence in high numbers in dried fruits and vegetables, as observed in this study, implies poor hygiene and sanitary conditions during processing (Oranusi and Braide, 2012).

Absence of FC and TC in commercially dried fruits (Table 4) may signify good hygienic and handling practices. Generally, this is an indication of minimum adherence to Good Health Practices (GHP) and Good Manufacturing Practices (GMP) applied to commercially dried fruits and vegetable products as stipulated by the Joint FAO/WHO Codex Alimentarius Commission (1994). Furthermore, the low pH (3.41 - 4.63) of the food products (Table 3) may also explain the absence. Absence of the possible microbial pathogens can also be attributed to the fact that, unlike home dried foods, many commercially dried food products undergo specific pathogen reduction treatments to reduce potential hazards for consumers (FAO/WHO, 2014). In contrast, a study (Witthuhn et al., 2005) in South Africa, from which most if not all commercially dried fruits are imported, and others in other parts of the region (Boyacioglu and Gönül, 1990; Olsen et al., 2000) revealed presence of pathogenic microorganisms and their toxins in these products. These studies identified species such as *Salmonella, E. coli, Staphylococcus, Clostridium,* and high levels of fungi.

The commercially produced food products analysed were mostly fruits such as peaches, mangoes, prunes, pears, apricots, raisins, dates and guavas. Typically, fruits have low pH (Uzeh et al., 2009) since fruits increase in acidity as they ripen and this may not favour growth of pathogenic microorganisms (see Table 4 under commercially dried products), although some moulds and yeasts can endure such high acidity. Thus, the considerable counts of TAC ($5.4×10^1$ - $1.0×10^3$ CFU g^{-1}) and fungi ($2.0×10^2$ - $6.3×10^3$ CFU g^{-1}) in these fruits could be due to the high a_w (0.78 - 0.83). Witthuhn et al. (2005) report that fungi are the main causes of the spoilage of dried high-moisture fruits. Additionally, Sagar and Suresh, (2010) observe that fungi are more tolerant to reduced water activity than bacteria and grow even below 0.80. Generally, food products with high a_w have substantial amount of unbound water molecules that support growth and survival of microorganisms favourably (El-Halouat et al., 1998; Ferrati et al., 2005).

Unhygienic conditions, combined with poor sanitary environments could account for the presence of pathogenic microorganisms in home dried fruits and vegetables. For instance, slicing of the fruits and vegetables for drying is often done in the open and with bare hands and this subjects the products to possible microbial contamination. The pieces are also dried in the open in full sun for some days, which further exposes the products to possible contamination. However, results for unpeeled peaches and apples, in which FC and TC were not detected, were in line with Gilbert et al. (2000) guidelines. Equally, TAC values for these fruits were within the acceptable levels recommended by Gilbert et al. (2000). Within these produce, TAC ranged from $2.0x10^2$ to $1x10^3$ CFU g^{-1}. In contrast, leafy vegetables such as spinach, traditional vegetable and pumpkin leaves were highly contaminated with TAC, followed by TC and FC. While TAC ranged from $9.2x10^5$ to $6.7x10^6$ CFU g^{-1}, TC ranged from $3.5x10^6$ to $7.7x10^7$ CFU g^{-1} and FC from $6.5x10^1$ to $4.0x10^4$ CFU g^{-1}. Verma and Joshi (2000) highlight that dried vegetables tend to record higher levels of contamination than dried fruits. The low a_w, coupled with the high sugar and/or fat content in these vegetables, can enhance the survival and heat resistance of microorganisms in these foods (Beuchat et al., 2013; Finn et al., 2013).

These results concur with the findings by Amoah et al. (2006), who report heavy faecal coliform contamination in vegetables (ranging from $4.0 × 10^3$ to $9.3 × 10^8$ MPN/g) in Ghana. Halablab et al. (2011) and Mensah et al. (2002) ascribe microbial contamination in vegetables to sources such as soil, manure, water and poor post-harvest handling and storage. Significantly, leafy vegetables such as spinach, traditional vegetable and pumpkin leaves grow closer to the ground, hence are more easily contaminated from soil microorganisms as compared to apples and peaches which are high up the tree bushes, far away from soil microbial contaminants (Bello et al., 2014). Generally, if the soil has been treated with poor quality animal manure as fertilizer or irrigated with contaminated water, vegetables are also likely to be affected.

According to Beuchat (2006), vegetables are among the food groups implicated with greater frequency in recent years, in causing enteric diseases through use of treated or fully composited animal manure (Johannessen et al., 2002). Irrigation of vegetables through use of drip rather than spray/overhead and flood have been noted to reduce this effect (Aycicek et al., 2006). On the other hand, higher pH in leafy vegetables (6.69 - 8.27) in this study may also promote growth of these microorganisms unlike the acidic (4.03 - 4.53) nature of most fruits which tend to inhibit pathogenic growth (Bello et al., 2014).

Dried leafy vegetables produced at home (spinach, traditional vegetable and pumpkin leaves) were highly contaminated with fungi (ranging from $6.5×10^5$ to $9.4×10^5$ CFU g^{-1}) followed by unpeeled dried peaches ($3.1×10^3$ CFU g^{-1}). Commercially dried fruits such as guavas, dates, prunes and mangoes also recorded high fungal contamination levels, ranging from $3.8x10^3$ to $6.3×10^3$ CFU g^{-1}. According to the recommended guidelines for dried fruits and vegetables, the yeast and fungi counts should not exceed $1.0×10^3$ CFU g^{-1} (Witthuhn et al., 2005). Among the commercially produced dried fruits, the lowest fungi counts were detected in pears (2.0×10^2 CFU g^{-1}) followed by peeled peaches (2.6×10^2 CFU g^{-1}) and then in apricots (7.2×10^2 CFU g^{-1}). While fungi and total aerobic counts in the current study were recorded in less than 50% of the samples, Witthuhn et al. (2005) reports their presence in almost all products examined in South Africa. Nonetheless, as presented in Table 4, low counts of fungi were also recorded in home dried fruits such as apples (3.9×10^2 CFU g^{-1}) and peeled peaches (4.0×10^2 CFU g^{-1}). Beuchat and Mann (2014) recommend that dried fruits should be subjected to a lethal process and further contamination prevented before they are consumed.

Notably, possible pathogenic microorganisms, except *Clostridium spp*, were detected in all home dried leafy vegetables (Table 4). *E. coli* (9.0×10^1 - 3.2×10^2 CFU g^{-1}) and *Bacillus* spp (5.6×10^1 - 6.1×10^1 CFU g^{-1}) were detected in spinach, traditional vegetable and pumpkin leaves. While *Salmonella* spp was absent in spinach, it was detected in traditional vegetable (10 CFU g^{-1} detected on BGA). In pumpkin leaves, *Salmonella* spp and *Shigella* spp were detected both on BGA (3.0×10^1 CFU g^{-1}) and SSA (6 CFU g^{-1}).

The most contaminated home dried vegetable were pumpkin leaves, followed by traditional vegetable and then spinach. Correspondingly, several studies also report the presence of these pathogens in semi processed vegetables (Abadias et al., 2008; Beuchat, 1996; Beuchat, 2002; National Advisory Committee on Microbiological Criteria for Foods, 1999) though they significantly vary. According to European Commission Scientific Committee on Food (2002), while pathogenic *E. coli* is more frequently isolated as compared to *Salmonella*, the prevalence of *Salmonella* is generally high in vegetables, ranging between 4 and 8%. Likewise, in these leafy vegetables, *Salmonella* prevalence ranged between 33 and 67% while *E. coli* was present in all the vegetables (Table 4). *Salmonella* has been reported to survive on dried food products for up to eight months (Beuchat and Mann, 2014). It is acknowledged that, while traditional processing interventions such as drying are effective when applied to high moisture foods, they often fail to reduce microbial hazard contamination of LMF significantly and to non-detectable levels (Beuchat et al., 2013; FAO/WHO, 2014; Finn et al., 2013). Because home drying temperature is usually not high enough to kill contaminating microorganisms, blanching of fruits and vegetables before drying is recommended in order to reduce the microbial load and also to prevent colour changes.

More than 60% of the samples did not meet the international standards; thus not recommended for human consumption. The high microbial counts in home dried fruits and vegetables sold on the market in Maseru makes them unsuitable for human consumption. A global review on the prevalence of pathogenic microbial contamination ($>10^3$ CFU g^{-1}) in dried fruits and vegetables reported a prevalence of about 4.84% (FAO/WHO, 2014). To limit introduction of pathogenic microorganisms in dried vegetable products, especially in leafy vegetables, their respective pre and post-harvest sources of contamination that include soil, faeces, irrigation and rinse water, dust, insects, inadequately composted manure, wild and domestic animals, and unhygienic processing equipment and human handling should be minimised (Beuchat, 1996; Burnett and Beuchat, 2001). *E. coli* and *Salmonella* can be found in animal faeces or from contaminated sources of water used for both irrigation and further processing. According to Solomon et al. (2002) and National Advisory Committee on Microbiological Criteria for Foods (1999), spreading of *E. coli* from manure-contaminated soil and irrigation water to subsequent processed vegetables has been reported.

Importantly, during processing, stringent quality control measures need to be taken and enforced in order to reduce pathogenic prevalence in dried fruits and vegetables. To enable this, government has to play a pivotal role in coming up with appropriate legislation that should be incorporated into existing food safety regulations and implemented. In addition, government needs to draw a food safety control policy and develop stringent quality control measures for such products at the market place and stores. Once the policy is in place it should act as a guideline to regulatory authorities such as local municipal authorities, analytical labs and food standard authorities who should then enforce the policy. Thereafter, appropriate food safety training, including Hazard Analysis and Critical Control Points (HACCP), Good Manufacturing Practices (GMP) and Good Hygienic Practices (GHP) should be initiated since they can significantly reduce pathogenic hazards in foods (Blumenthal et al., 2000; Ijabadeniyi and Buys, 2012). Lastly, the Joint FAO/WHO Codex Alimentarius Commission (1994) guidelines on processing dried vegetables and fruits should be followed stringently to reduce the risk of post-harvest contamination. One major limitation of this study is that potential microbial pathogens were identified only to the genus level and not to species level, which would confirm pathogenicity and improve the results of the study.

Conclusions

In this study, more than half of the samples analysed were disqualified from human consumption due to poor microbial quality, which fell short of meeting international standards. The presence of possible pathogenic species on food products poses a potential public health hazard to consumers. Therefore, the findings from this study highlight the importance and need for adequate processing of home dried fruits and vegetables.

Responsible authorities have to embrace measures and policies focused on food safety and hygienic practices through practical education and re-training programs for food business operators at all steps of food production (from farm to folk), especially the home based producers. Also, once these measures are in place they need monitoring and enforcement through properly gazetted food laws and regulations. The findings from this study can be valuable for further risk assessment of the impact on human health of consuming, especially, home dried fruits and vegetables.

Conflict of interests

The authors have not declared any conflict of interest.

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REFERENCES

Abadias M, Usall J, Anguera M, Solsona C, Viñas I (2008). Microbiological quality of fresh, minimally-processed fruit and vegetables, and sprouts from retail establishments. Int. J. Food Microbiol. 123:121-129.

Amoah P, Drechsel P, Abaidoo R, Ntow W (2006). Pesticide and Pathogen Contamination of Vegetables in Ghana's Urban Markets. Arch. Environ. Contam. Toxicol. 50:1-6.

AOAC (2000). Official methods of analysis of AOAC International, Gaithersburg, MD, USA, AOAC International.

APHA (2001). Compendium of Methods for the Microbiological Examination of Foods, Washington, DC, American Public Health Association (APHA).

Aycicek H, Oguz U, Karci K (2006). Determination of total aerobic and indicator bacteria on some raw eaten vegetables from wholesalers in Ankara, Turkey. Int. J. Hyg. Environ. Health 209:197-201.

Barkai-Golan R, Paster N (2011). Mycotoxins in Fruits and Vegetables, Elsevier Science.

Barth M, Hankinson T, Zhuang H, Breidt F (2010). Microbiological spoilage of fruits and vegetables. Compendium of the Microbiological Spoilage of Foods and Beverages, New York: Springer.

Bello O, Bello T, Fashola M, Oluwadun A (2014). Microbiological quality of some locally-produced fruit juices in Ogun State, South western Nigeria. *E3* J. Microbiol. Res. 2(1):1-8.

Beuchat L (1996). Pathogenic microorganisms associated with fresh produce. J. Food Prot. 59:204-216.

Beuchat L (2002). Ecological factors influencing survival and growth of human pathogens on raw fruits and vegetables. Microbes Infect. 4:413-423.

Beuchat L (2006). Vectors and conditions for pre-harvest contamination of fruits and vegetables with pathogens capable of causing enteric diseases. Brit. Food J. 108: 38-53.

Beuchat L, Komitopoulou E, Beckers H, Betts R, Bourdichon F, Fanning S, Joosten H, Ter Kuile B (2013). Low–water activity foods: increased concern as vehicles of foodborne pathogens. J. Food Prot. 76(1): 150-172.

Beuchat L, Mann D (2014). Survival of salmonella on dried fruits and in aqueous dried fruit homogenates as affected by temperature. J. Food Prot. 77(7):1102-1109.

Blumenthal U, Mara D, Peasey A, Ruiz-Palacios G, Stott R (2000). Guidelines for the microbiological quality of treated wastewater used in agriculture: recommendations for revising WHO guidelines. *B.* World Health Organ. 78(9):1104-1116.

Boyacioglu D, Gönül M (1990). Survey of aflatoxin contamination of dried figs grown in Turkey in 1986. Food Addit. Contam. 7(2):235-237.

Burnett S, Beuchat L (2001). Human pathogens associated with raw produce and unpasteurized juices, and difficulties in contamination. J. Ind. Microbiol. Biotechnol. 27:104-110.

De Sousa C (2008). The Impact of Food Manufacturing Practices on Food borne Diseases. Braz. Arch. Biol. Technol. 51(4):815-823.

ECSCF (2002). Risk Profile on the Microbiological Contamination of Fruits and Vegetables Eaten Raw. Report of the Scientific Committee on Food, . Brussel - Belgium: European Commission Scientific Committee on Food.

El-Halouat A, Gourama H, Uittendaele M, Debevere J (1998). Effects of modified atmosphere packaging and preservatives on the shelf-life of high moisture prunes and raisins. Int. J. Food Microbiol. 41:177-184.

Erickson M, Doyle M (2012). Plant Food Safety Issues: Linking Production Agriculture with One Health. In: Institute of Medicine (US). Improving Food Safety Through a One Health Approach: Workshop Summary. Washington (DC): National Academies Press (US); 2012. A3. Available at: http://www.ncbi.nlm.nih.gov/books/NBK114507/.

FAO/WHO (2014). Ranking of Low Moisture Foods in Support of Microbiological Risk Management: Preliminary report of FAO/WHO expert consultation on ranking of low moisture foods. Part I – Main Report. Rome/ Geneva: FAO/ WHO.

Ferrati A, Tavolaro P, Destro M, Landgraf M, Franco B (2005). A comparison of ready to use systems for evaluating the microbiological quality of acidic fruit juices using non-pasteurized orange juice as an experimental model. Int. J. Food Microbiol. 8:49-53.

Finn S, Condell O, McClure P, Amézquita A, Fanning S (2013). Mechanisms of survival, responses and sources of Salmonella in low-moisture environments. Front. Microbiol. 4:1-15.

Food Safety Programme (2002). WHO global strategy for food safety : safer food for better health. Geneva, Switzerland.

Gilbert R, De-Louvois J, Donovan T, Little C, Nye K (2000). Guidelines for the microbiological quality of some ready-to-eat foods samples at the point of sale. Commun. Dis. Public Health 3:163-167.

Halablab A, Sheet H, Holail M (2011). Microbilogical quality of raw vegetables grown in Bekaa Valley, Lebanon. Am. J. Food Technol. 6(2):129-139.

Ijabadeniyi O, Buys E (2012). Irrigation water and microbiological safety of fresh produce; South Africa as a case study: A review. Afr. J. Agric. Res. 7(35):4848-4857.

Johannessen G, Loncarevic S, Kruse H (2002). Bacteriological analysis of fresh produce in Norway. Int. J. Food Microbiol. 77:199-203.

Joint FAO/WHO Codex Alimentarius Commission (1994). *Codex Alimentarius,* Rome, Food and Agriculture Organisation.

Kaleta A, Górnicki K, Winiczenko R, Chojnacka A (2013). Evaluation of drying models of apple (var. Ligol) dried in a fluidized bed dryer. Energy Convers. Manage. 67:179-185.

Karam M, Petit J, Zimmer D, Baudelaire D, Scher J (2016). Effects of drying and grinding in production of fruit and vegetable powders: A review. J. Food Eng. 188:32-49.

Leistner L (1992). Food preservation by combined methods. Food Res. Int. 25(2):151-158.

Lukinmaa S, Nakari U, Eklund M, Siitonen A (2004). Application of molecular genetic methods in diagnostics and epidemiology of food-borne bacterial pathogens. APMIS 12:908-929.

Lund B, Baird-Parker T, Gould G (2000). Microbiological Safety and Quality of Food, Maryland, Springer.

Mensah P, Yeboah-Manu D, Owusu-Darko K, Ablordey A (2002). Street foods in Accra, Ghana: How safe are they? B. World Health Organ. 80:546-554.

National Advisory Committee on Microbiological Criteria for Foods (1999). Microbiological safety evaluations and recommendations on fresh produce. Food Control 10:117-143.

Ntuli V, Bekele M, Molebatsi N, Makotoko M, Chatanga P, Asita A (2013). Microbial and physicochemical characterization of maize and wheat flour from a milling company, Lesotho. Internet J. Food Saf. 15:11-19.

Olsen S, MacKinon L, Goulding J, Slutsker L (2000). Surveillance for foodborne disease outbreaks–United States, 1993-1997. Morbidity and Mortality Weekly Report.

Oranusi U, Braide W (2012). A study of microbial safety of ready-to-eat foods vended on highways: Onitsha-Owerri, south east Nigeria. Int. Res. J. Microbiol. 3(2):066-071.

Prescott L, Hardy M, Klein J (2001). Microbiology, New York, McGraw Hill.

Sagar V, Suresh K (2010). Recent advances in drying and dehydration of fruits and vegetables: a review. J. Food Sci. Technol. 47(1):15-26

Solomon E, Yaron S, Matthews K (2002). Transmission of Escherichia coli O157:H7 from contaminated manure and irrigation water to lettuce plant tissue and its subsequent internalization. Appl. Environ. Microbiol. 68:397-400.

Thyagarajan D, Ashok A (2014). *Recent Trends in Food Processing* - The Global Scenario, Oxford, Satish Serial Publishing House.

Unicomb L, Simmons G, Merritt T, Gregory J, Nicol C, Jelfs P, Kirk M, Tan A, Thomson R, Adanopoulos J, Little C, Currie A, Dalton C (2005). Sesame seed products contaminated with Salmonella: three outbreaks associated with tahini. Epidemiol. Infect. 133:1065-1072.

Uzeh R, Alade F, Bankole M (2009). The microbial quality of prepacked mixed vegetables salad in some retail outlets in Lagos, Nigeria. Afr. J. Food Sci. 3(9):270-272.

Verma L, Joshi V (2000). Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation, and Waste Management, New Dehli, Indus Publishing Company.

Vivas A, Gelaye B, Aboset N, Kumie A, Berhane Y, Williams M (2010). Knowledge, attitudes, and practices (KAP) of hygiene among school children in Angolela, Ethiopia. J. Prev. Med. Hyg. 51(2):73-79.

WHO. (2009). WHO Country Cooperation Strategy, 2008-2013, Lesotho [Online]. World Health Organisation. Available at: http://www.afro.who.int/en/lesotho/lesotho-publications.html

Wilhelm L, Suter D, Brusewitz G (2004). Drying and Dehydration. Food and Process Engineering Technology. St. Joseph, Michigan: ASAE: American Society of Agricultural Engineers.

Witthuhn R, Engelbrecht S, Joubert E, Britz T (2005). Microbial content of commercial South African high-moisture dried fruits. J. Appl. Microbiol. 98:722-726.