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Microbial and heavy metal contamination of pineapple products processed by small and medium scale processing enterprises in Rwanda

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Fruit products are increasingly consumed but highly prone to microbial deterioration if not adequately processed and stored. The present study was conducted to evaluate the microbial and heavy metal concentrations of packed pineapple nectars, syrups and jams processed by 10 Small and Medium scale pineapple processing Enterprises (SMEs) over a storage duration of 12 months. Collected samples were analysed to determine whether the levels of microbial and heavy metal concentrations were in line with maximum permissible limits set by Codex Alimentarius Commission (CAC), East African Standards (EAS) and Rwanda Bureau of Standards (RBS). The samples were tested for yeasts and moulds, total plate counts, Faecal coliforms, total coliforms, *Escherichia coli*, *Salmonella*, *Shigella* and *Staphylococcus aureus* using tested International Organization for Standardization (ISO) microbial determination methods. Quantitative determination of heavy metals: zinc, iron, lead, copper, cadmium and aluminium was carried out by Atomic Absorption Spectrophotometer (AAS). Pineapple products were free from most of the microorganisms but only nectars from 30% of SMEs were highly contaminated above the permissible Codex and RBS limits with total plate counts >300 CFU/ml and yeasts and mould counts >300 CFU/ml. The mean levels of zinc, iron, copper and aluminium were within the acceptable recommended Codex and RBS standard values but the levels of lead and cadmium were above those permissible standard values. These results indicated that some fruit processors in Rwanda may not be observing good manufacturing and hygienic practices, leading to a need for improved post-harvest and processing guidelines, better monitoring and enforcement, and additional research into heavy-metal ingress in the manufacturing process.

Key words: Pineapple, juices, jams, microbial contamination, heavy metal, Rwanda.

INTRODUCTION

Pineapple [*Ananas comosus* (L.) Merrill.] is an important tropical fruit. The Philippines, Brazil, Costa Rica, Thailand and China are the main pineapple producing countries in the world, whereas France, Belgium, USA, Netherlands and Japan are the global lead consumers of pineapple products (United Nations Conference on Trade and Development /UNCTAD, 2012). In the last 10 years, the world trade of fresh pineapple, juices and canned fruit

has doubled and the pineapple export industry has developed into a complex export supply chain (UNCTAD, 2012). In Rwanda, pineapple production has increased and it was expected that the production would increase from 30,000 tonnes in 2006 to 120,000 tonnes in 2012 (RHODA, 2008). In order to improve on their income, small and medium scale pineapple processing enterprises have started value addition processes to the pineapple fruit by transforming the fruit into varied processed products namely juices, jams, wines and dried slices (Austin et al., 2009). These products are highly prone to microbial deterioration if not adequately processed and stored (Osuntogum and Aboaba, 2004). A large number of lactic acid bacteria, coliforms, yeasts and moulds cause spoilage of fruit products by fermenting carbohydrates to produce undesirable changes such as production of acids, alcohols and diacetyls affecting the organoleptic properties of the food products (Tribst et al., 2009). Such spoiled products cannot get to the export market since their quality cannot meet the international quality requirements including microbiological quality. Food spoilage can result in health problem as well as economic losses (Loureiro and Querol, 1999).

Codex Alimentarius Commission has limits for certain microorganisms including yeasts and moulds, total plate counts, faecal coliforms, total coliforms, *Escherschia coli*, *Salmonella*, *Staphylococcus aureus* and *Streptococcus faecalis* (Rwanda Standard, 2005). For example the maximum limits which should not be exceeded in concentrated pineapple juice are: total viable counts (10^3 CFU/ml), yeasts and moulds (<1 CFU/ml), coliforms (<1CFU/ml), *E. coli* (<1CFU/ml) *S. aureus* (<1 CFU/ml) and *Salmonella* (<1 CFU/ml). For the jam, the maximum limits are the same as juice but the values are expressed as CFU/g with the exception of total plate counts that should not exceed 10^2 CFU/g (Rwanda Standard, 2008).

Fruit products including pineapple products may provide significant exposure routes to heavy metal contamination and the effect of some metals such as lead and cadmium at low levels have been well proven and their levels above the permissible limits are shown to contribute to serious health problems such as cardiovascular, nervous, kidney as well as bone diseases (Jarup, 2003). Other elements such as aluminium, zinc, iron and copper are very important to human health at very low levels but can lead to toxicity once ingested in high doses (Plum et al., 2010).

Heavy metals are found in the environment either naturally or anthropogenically and their concentration are elevated through waste disposal, smelter stacks atmospheric deposition, fertiliser and pesticides and the application of sludge in arable land (Sobukola et al., 2010; Zheng et al., 2007; Damirözü and Saldamli, 2002). They are non-biodegradable, thermo-stable and can accumulate to toxic levels (Ramesh and Murphy, 2012). Under certain conditions, either essential micronutrients such as copper, zinc and iron or toxic elements such as mercury (Hg), lead (Pb) and cadmium (Cd) in the environment can accumulate to a toxic concentration level, which can result in health damages (European Environment and Health Information System, 2009; Jefferies et al., 1984). Food consumption is one of the major pathways of human exposure to heavy metals and it counts more than 90% of the rest of the other ways of exposure namely inhalation and dermal contact (Loutfy et al., 2006).

Since the increase in numbers of small scale pineapple processing enterprises in Rwanda, there has not been adequate information regarding microbiological and toxicological quality of the processed products. The objective of the current study was therefore to evaluate the effect of storage conditions on microbiological quality and heavy metal contamination of the processed pineapple products by small and medium scale pineapple processing enterprises in Rwanda. The results were measured against their compliance to Rwanda Bureau and Codex Standards requirements.

MATERIALS AND METHODS

Microbiological analysis of juice and jam samples

Processed pineapple juices (nectars and syrups) and jams were collected from 10 pineapple processing enterprises across the country in October 2012. All samples were bottled in plastic bottles for juices and plastic jars for jams at about 40°C. Bottles were manually capped. From each enterprises, 18 bottles (500 ml each bottle) of nectars, 18 bottles (500 ml each bottle) of syrups and 18 jars (250 g each jar) of jams were randomly collected. Samples were immediately transported to the Laboratory of Analysis of Foodstuff, Drugs, Water and Toxics (LADAMET) of the faculty of Medicine at the University of Rwanda (UR). Samples which were not analyzed within 24 h were kept in a refrigerator at 4°C for further analysis of microbial contamination of pineapple products at the initial storage time. Another batch of samples was kept at room temperature (21 to 25°C) for further microbial analysis over storage times of 12 months for syrups and jams and two months for nectars. Microbial analysis was performed every three months for syrups and jams and every one month for nectars. All samples were analyzed for microbial contamination using International Organization for Standardization (ISO) methods (ISO, 1999; ISO, 2001; ISO, 2002; ISO, 2006). All culture media used were manufactured by Biokar, France.

Enumeration of microorganisms

One gram and or one milliltre sample was taken from each pineapple jam jar and or juice bottle under asceptic conditions. It was then placed in sterile test tube containing 9 ml of 0.2%

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Table 1. Microbiological quality of pineapple nectars over a storage period of two months (CFU/ml).

Sample	YM	TPC	TC	FC	*E. coli*	SA	SF	S
N_1	<1*	<1	<1	<1	nd	<1	<1	nd
N_2	<1	<1	<1	<1	nd	<1	<1	nd
N_3	>300	>300	<1	<1	nd	<1	<1	nd
N_4	<1	<1	<1	<1	nd	<1	<1	nd
N_5	<1	<1	<1	<1	nd	<1	<1	nd
N_6	>300	>300	<1	<1	nd	<1	<1	nd
N_7	<1	<1	<1	<1	nd	<1	<1	nd
N_8	>300	>300	<1	<1	nd	<1	<1	nd
N_9	<1	<1	<1	<1	nd	<1	<1	nd
N_{10}	<1	<1	<1	<1	nd	<1	<1	nd

N1-N10 represent nectar samples from different pineapple enterprises; *: The values represent the mean of microbial population counts detected at the initial storage time, the end of first and second month of storage. nd, not detected; YM, yeasts and moulds; TPC, total plate count; TC, total coliforms; FC, faecal coliforms; E. Coli, *Escherichia coli*; SA, *Staphyloccocus Aureus*; SF, *Streptococcus faecalis*; S, *Salmonella* spp.

peptone water and shaken at a speed of 2200 revolution per minute (rpm) for 2 min. This gives a 10^{-1} dilution. Further serial dilutions were prepared up to 10^{-5}. Each serial dilution for nectars, syrups and jams was spread-plated in terms of 0.1 ml in triplicate on Sorbitol McConkey Agar (SMAC) for determination of *E. coli* (ISO 16649-2:2001), xylose lysine, deoxycholate agar for determination of *Salmonella* spp. after pre-enrichment in peptone water and enrichment on Rappaport Vassiliadis medium with soya as indicated by ISO (ISO 6579:2002), horizontal method for detection of *Salmonella* spp). Total plate count agar was used for total plate counts (ISO 4833:2003 colony counting technique at 30°C). The counting of microorganisms was done after 72 h of incubation of Petri dishes at 30°C. Yeasts and moulds were counted on Potato Dextrose Chloramphenicol agar after 72 h of incubation of Petri dishes at 25°C (ISO 7954:1987, colony counting technique at 25°C). Baird Parker Agar medium with addition of egg yolk tellurite emulsion was used for determination of *S. aureus* (commercial preparation was available) (ISO6888-1). The counting of all Enterobacteriaceae was done after incubation of Petri dishes for 48 h at 37°C (ISO 4832:1991 colony counting method). The enumeration of total coliforms was done after 48 h of incubation at 37°C of Petri dishes containing the violet red bile lysine agar medium (ISO 4832-2006 (E)). All culture media were prepared according to the indicated guidelines by the manufacturer (Biokar, France) and the results were expressed as CFU/ml for juices or CFU/g for jams.

Determination of heavy metals

Acid digestion was performed by placing 20 g of each jam sample and or 20 ml of juice/water in a 100 ml volumetric flask. Then, 10 ml of a concentrated hydrochloric acid (1%) were added to the sample and thoroughly mixed. After 30 min, the mixture was made up to volume of 100 ml with distilled deionised water. The solution was again mixed thoroughly and filtered using filter paper (no. 389) and a funnel. The solution was then stored in a refrigerator at 4°C for analysis. Minimal dilution of the sample was chosen to provide a more concentrated digestate solution so that a lower concentration can be measured in the sample. In this case, dilution factor of five was used (Perkin-Elmer Corporation,1996).

Standard stock solutions for Cu, Zn, Fe, Pb, Cd and Al were used. Series of working standards were prepared by addition of the blank solution of HCl (1%), distilled- deonised water and HNO_3 (1%) as cleaning solutions. The blanks were used for zeroing the instrument before each analysis to avoid matrix interference. Appropriate quality assurance procedures and precautions (including calibration of AAS repeated periodically) were carried out to ensure reliability of the results and samples were carefully handled to avoid cross-contamination. All chemicals used were of reagent grade (high purity HNO_3 (65%), HCl (37%); Merck, Germany). Before starting any analysis, all equipment and containers were soaked in 10% HNO_3 for 24 h and rinsed touroughly with distilled water before use. Distilled-deonised water was used throughout the study. Reagent blank determinations were used to correct the instrument readings. The analyses were performed using Atomic Absorption Spectrophometer (AAS) (Perkin-Elmer, model 200). For validation of the analytical procedure, repeated analyses of the samples were done three times and the appropriated lamps such as multilamp for copper and iron (Fe) and unilamp for zinc (Zn), Cadmium (Cd), lead (Pb) and Aluminium (Al) were used.

Statistical analysis

Microbiological and heavy metal data was captured into Microsoft Excel Software, version 2010 which was also used to calculate means and standard deviations.

RESULTS AND DISCUSSION

Microbial counts

Results show that at the initial stage, after the second and the third month of storage at room temperature, pineapple nectars from 70% of both enterprise categories complied with the Codex and Rwanda Standard requirements. The results for two months of storage are given in (Table 1). According to Codex Alimentarius Commission (2003), yeasts and moulds, total coliforms, faecal coliforms, *E. coli*, *Salmonella* spp. and *S. aureus* should be absent in pineapple fruit juices and jams.

The remaining 30% of the visited enterprises had their

Table 2. Microbiological quality of pineapple syrups over a storage period of 12 months (CFU/ml).

Sample	YM	TPC	TC	FC	*E. coli*	SA	SF	S
S_1	<1*	<1	<1	<1	nd	<1	<1	nd
S_2	<1	<1	<1	<1	nd	<1	<1	nd
S_3	<1	<1	<1	<1	nd	<1	<1	nd
S_4	<1	<1	<1	<1	nd	<1	<1	nd
S_5	<1	<1	<1	<1	nd	<1	<1	nd
S_6	<1	<1	<1	<1	nd	<1	<1	nd
S_7	<1	<1	<1	<1	nd	<1	<1	nd
S_8	<1	<1	<1	<1	nd	<1	<1	nd
S_9	<1	<1	<1	<1	nd	<1	<1	nd
S_{10}	<1	<1	<1	<1	nd	<1	<1	nd

S_1-S_{10} represent syrups samples different pineapple enterprises. The values represent the mean of microbial population counts detected at 0, 3,6,9 and 12 month of storage. nd, not detected; YM,Yeasts and Moulds; TPC, Total Plate Count; TC, Total Coliforms; Faecal Coliforms; E. Coli: *Escherichia coli*; SA, *Staphyloccocus Aureus*; SF, *Streptococcus Faecalis*; S, *Salmonella* spp

Table 3. Microbiological quality of pineapple jam samples over a storage period of 12 months (CFU/ml).

Sample	YM	TPC	TC	FC	*E. coli*	SA	SF	S
J_1	<1*	<1	<1	<1	nd	<1	<1	nd
J_2	<1	<1	<1	<1	nd	<1	<1	nd
J_3	<1	<1	<1	<1	nd	<1	<1	nd
J_4	<1	<1	<1	<1	nd	<1	<1	nd
J_5	<1	<1	<1	<1	nd	<1	<1	nd
J_6	<1	<1	<1	<1	nd	<1	<1	nd

J_1-J_6 represent jam samples from different pineapple enterprises. The values represent the mean of microbial population counts detected at 0,3,6,9 and 12 month of storage. nd: not detected ; . nd, not detected; YM, yeasts and moulds; TPC, total plate count; TC, total coliforms; FC, Faecal coliforms; E. Coli, *Escherichia coli*; SA, *Staphyloccocus Aureus*; SF, *Streptococcus faecalis*; S, *Salmonella* spp

ready to drink pineapple nectars contaminated above the acceptable limits of yeasts and moulds. Total plate counts were estimated at > 2.47 log CFU/ml. These results corroborate with the results reported by Tournas et al. (2006) where 22% of 65 pasteurised juices from the retail markets were contaminated with yeasts and moulds with counts ranging from 1 to 6.83 log CFU/ml. Tribst et al. (2009) argued that such contamination may be due to post-pasteurisation contamination or highly contaminated raw material used. This was obvious in this case since at the second month of storage, the juices nectars from those three enterprises had already shown abundant gas formation, which deformed and sometimes broke up the plastic packages. Besides that, there was formation of films and off flavour with a fermentation smell (alcohol and esters) and undesirable taste. These are typical indication of yeast and mould contamination in fruit juices during their storage time (Tournas et al., 2006; Loureiro and Queroly, 1999).

The presence of high load of yeasts and moulds in these ready to drink juices nectars may be due to poor hygiene conditions at these small scale enterprises. These enterprises do not have a proper food processing environment as set by Codex Alimentarius Commission in the good hygienic and good manufacturing practices regulations at food processing enterprise levels (Austin et al., 2009). In addition, the sterilization of the processed products was not fully completed because since it has been proven that the shelf-life of fruit juice can be prolonged by conventional heat treatment to inactivate enzymes and microorganisms (Bates et al., 2001). The product has therefore to be subjected to a heat treatment of 70°C for 30 min, followed by filling and a rapid heating at 90°C for a holding time of 30 s with rapid cooling as suggested by Aguilar-Rosas et al. (2007) and Bates et al. (2001). This is a challenge to the studied enterprises that do not have in place a standard pasteurizing system and which sterilise the product employing boiling pots and package in plastic containers at 40°C (Mukantwali et al., 2013). Pineapple syrups and jams evaluated quarterly for 12 months did not show any microbial growth during the storage period (Tables 2 and 3).

The inhibition of microbial growth in these products may be due to the presence of sulphur dioxide, high

Table 4. Heavy metal concentrations in pineapple nectars (mean±SD in mg/l).

Nectars	Cu	Fe	Pb	Zn	Cd	Al
N_1	0.74±0.01	1.35±0.01	0.86±0.00	1.74±0.01	0.43±0.22	3.00±0.00
N_2	1.01±0.00	1.53±0.11	0.59±0.00	0.83±0.00	0.32±0.16	2.31±0.02
N_3	3.13±0.11	1.76±0.01	0.74±0.02	0.9±0.11	0.37±0.15	2.36±0.02
N_4	2.66±0.15	1.2±0.12	0.55±0.02	2.7±0.15	0.30±0.11	2.56±0.02
N_5	2.86±0.05	0.96±0.01	0.78±0.00	2.34±0.057	0.41±0.14	3.28±0.02
N_6	1.15±0.01	1.05±0.01	0.80±0.00	1.85±0.011	0.21±0.10	2.34±0.02
N_7	1.01±0.00	1.39±0.01	0.25±0.00	1.82±0.006	0.23±0.12	2.36±0.02
N_8	1.13±0.05	1.76±0.01	0.98±0.00	0.64±0.057	0.21±0.10	3.15±0.05
N_9	1.75±0.01	1.48±0.02	0.75±0.00	0.95±0.015	0.05±0.03	3.73±0.02
N_{10}	2.86±0.01	1.64±0.00	0.62±0.00	2.32±0.015	0.25±0.10	2.31±0.02

N_1-N_{10} represent sample nectars from different enterprises. The results of the heavy metals given in this table are the average of three independent experiments. However, the levels of Pb and Cd, which ranged from 0.25 to 0.98 mg/l and 0.05 to 0.93 mg/l were above the permissible limits 0.3 mg/l and 0.1mg/l, respectively for these minerals. Higher levels of Pb and Cd than the recommended levels in the nectars, make these products unacceptable at local, regional and international markets.

Table 5. Heavy metal concentrations in pineapple syrups (mean±SD in mg/l).

Syrup	Cu	Fe	Pb	Zn	Cd	Al
S_1	3.26±0.34	0.95±0.00	0.08±0.00	2.17±0.05	0.75±0.15	4.10±0.05
S_2	3.50±0.00	1.15±0.00	0.42±0.00	2.49±0.00	1.23±0.22	3.18±0.07
S_3	3.19±0.00	1.01±0.01	0.03±0.00	1.22±0.00	0.26±0.26	2.80±0.00
S_4	0.24±0.15	0.95±0.64	1.74±0.53	1.01±0.31	0.13±0.19	3.76±0.02
S_5	2.66±0.00	1.92±0.02	0.87±0.00	1.32±0.00	0.77±0.44	3.31±0.02
S_6	3.17±0.00	1.23±0.02	0.98±0.00	2.21±0.00	0.75±0.63	3.38±0.05
S_7	2.55±0.00	1.65±0.00	0.05±0.00	0.63±0.00	0.00±0.00	2.65±0.00
S_8	2.68±0.00	1.13±0.05	0.25±0.00	2.67±0.00	0.02±0.03	3.31±0.02
S_9	2.94±0.00	1.35±0.00	0.52±0.00	1.80±0.00	0.02±0.03	3.93±0.05
S_{10}	2.77±0.00	1.05±0.00	0.81±0.00	1.45±0.00	0.65±0.24	2.93±0.02

S_1-S_{10} represent syrup samples from different enterprises. The results of the heavy metals given in this table are an average of three independent experiments

acidity, high sugar content and the effect of the heat treatment during processing as all these four factors are known to be inhibitors of microbial growth (Graham, 2000; Ewaidah, 1988). It has been reported that few bacteria grow below a pH value of 3.5 and this may be the reason why no single bacteria had grown in these products because the pH value of a pineapple juice was expected to be between 3 and 4 (United States Food and Drug Administration, 2007). In addition, inhibition of microbial growth could have been due to high levels of sugars (14.54 to 24.47%) resulting from overheating in syrup and jam products and use of preservatives. A preservative like sulphur dioxide (SO_2) is very detrimental to respiratory system of individuals (Fowie et al., 2006). Similar findings were reported by Basal and Rahman (2007) in Bangladesh where and the absence of total viable count growth in fruit juices was attributed may have been due to the use of higher preservatives than the recommended amount.

Heavy metals

Levels in nectars

Levels in ready to drink nectars from 10 processing enterprises (Table 4) show that, the concentrations of copper, iron, zinc and aluminium were lower than the maximum permissible levels set by the Codex Alimentarius Commission. Their values (with maximum permissible limits in brackets) ranged from 0.74 to 3.1 (5) mg/L for Cu; 0.96 to 1.76 (15) mg/L for Fe; 0.64 to 2.77 (5) mg/L for Zn and 2.28 to 3.73 (8) mg/L for Al.

Levels in syrups

Lower levels than the permissible limits of Cu, Fe, Zn and Al in juice syrups were observed (Table 5). Their concentrations ranged from 0.511 to 0.701 (5) mg/L for

Table 6. Heavy metal concentrations in pineapple jams (mean±SD in mg/kg).

Jams	Cu	Fe	Pb	Zn	Cd	Al
J_1	1.38±0.00	1.73±0.05	0.77±0.00	3.55±0.00	0.01±0. 01	5.00±0.25
J_2	2.04±0.00	2.83±0.05	0.55±0.00	2.16±0.00	0.31±0.32	7.91±0.28
J_3	2.47±0.00	2.53±0.05	0.46±0.00	2.97±0.00	0.58±0.23	7.67±0.06
J_4	3.29±0.00	2.13±0.05	0.33±0.00	0.82±0.00	0.80±0.13	4.50±0.00
J_5	.633±0.05	2.95±0.00	0.35±0.00	2.16±0.00	0.80±0.29	6.50±0.00
J_6	2.63±0.00	2.73±0.05	0.38±0.00	1.53±0.05	1.46±0.38	7.00±0.00

J_1-J_6 represent jam samples from different enterprises.The results of the heavy metals given in this table are the average of three independent experiments. Knowing the side effects of high ingestions of some of these minerals, there is a need of improving jam processing techniques so as to lower the concencetartions of the heavy metals before being taken to any market.

Cu; 1 to 2.7 (15) mg/L for Fe ; 0.63 to 2.675 (5) mg/L for Zn and 2.65 to 4.10 (8)mg/L for Al. The levels of Pb and Cd were above the permissible limits for 60 and 70% of syrups, respectively and ranged from 0.42 to 1.74 mg/L and 0.13 to 1.23 mg/L, respectively. Only 40 and 30% of the syrups had lower levels of Pb and Cd , respectively, ranging from 0.03 to 0.25 mg/L and 0.00 to 0.02 mg/L, respectively than the maximum limits of 0.3 and 0.1mg/L for Pb and Cd, respectively. It is important to note that the concentrations of Pb in the juices syrups were 11 to 18 times higher than the permissible limit of 0.05 mg/kg set by the Commission of the European Communities (CEC, 2006). Therefore, though the concentrations of the majority of measured heavy metals in both syrups and nectars were within the permissible concentration levels, their commercialisation is not still allowed either in Rwanda or elsewhere. High concentration of Pb causes detrimental side effects such as colic, constipation, anaemia, inducing high blood pressure and cardiovascular diseases in adults and foetal neuro-development and reduced learning capacity in children. High Cd ingestion is known to cause hemorrhaging digestive tract, damage of liver, kidneys and heart and many others (European Environment and Health Information System, 2009).

Levels in jams

Lower levels than the maximum permissible limits of Fe, Al and Pb in 67% of the jams were observed (Table 6). Their concentrations ranged from 1.73 to 2.95 mg/kg (15) mg/l for Fe and 4.50 to 7.91 (8) mg/kg for Al and 0.33 to 0.77 (1) mg/kg for Pb . The levels of Cu, Zn and Cd were above the permissible levels and ranged from 0.63 to 2.47 (0.03) mg/kg for Cu; 0.82 to 3.55 (0.05) mg/kg for Zn and 0.01 to 1.46 (0.01) mg/kg for Cd. Though copper and zinc are recognised to be essential trace elements for several biological functions in human body and though their toxicity is rare (Plum et al., 2010); it is of paramount that their levels be of acceptable standards in processed food products. From the current findings, it is possible that post-harvest, processing and preservation techniques were the source of the high levels of Zn and Cu since fruits, and consequently fruit products, are known to have very low concentrations in these trace elements (Wilson, 2014).

The damaging side effects of high concentrations of specific heavy metals indicates a need of improving jam processing techniques so as to lower the concentrations of the heavy metals prior to further marketing.

Levels in water from enterprises processing sites

The concentrations of some heavy metals in the samples of water collected from the enterprises are shown in Table 7. The results showed low concentrations of heavy metals in water that is used for processing pineapple products. The concentrations ranged from 0.02 to 0.30 mg/L for Cu; not detected to 0.041 for Fe; 0.03 to 2.54 for Zn; 0.03 to 0.56 for Mn and not detected to 0.08 for Cd. Lead was not detected in water samples. The present study revealed therefore that for commercial purposes, processed pineapple products by studied SMEs may pose risks to human health due to the high concentrations of heavy metals, such as Pb and Cd in juices and Cu and Zn in jams. This leads to suggestion that these products are not acceptable at local and even export market levels, knowing their side effects to human health once they are in high concentration. In addition, accessing EU market will not be possible since most of the EU countries had for example reported lead concentration in fruit juices ranging between 0.005 to 0.024 mg/kg (CEC, 2006). Since currently there is no knowledge about possible sources of contamination, it is necessary to establish levels of these metals by monitoring water quality, soil, plant and processing equipment for concen-tartion of these metals that could be a source of contamination and pose potential health hazards (Ramesh and Murphy, 2012).

Conclusions and recommendations

Results showed that pineapple products produced by SMEs in Rwanda were free from microorganisms except

Table 7. Heavy metal concentrations in water from processing enterprises (mean±SD in mg/l).

Water	Cu	Fe	Pb	Zn	Mn	Cd
W_1	0.17±0.05	nd*	nd	0.23±0.09	0.17±0.02	nd
W_2	0.24±0.03	0.412	nd	0.92±0.11	0.14±0.00	nd
W_3	0.30±0.07	0.027	nd	0.03±0.03	0.02±0.03	0.08±0.00
W_4	0.11±0.01	nd	nd	1.58±0.47	0.08±0.00	0.04±0.00
W_5	0.09±0.05	0.102	nd	0.85±0.06	0.56±0.03	nd
W_6	0.02±0.02	nd	nd	0.30±0.14	0.25±0.04	nd
W_7	0.22±0.00	nd	nd	2.54±0.13	0.06±0.02	0.05±0.00
W_8	0.14±0.04	nd	nd	0.21±0.07	0.04±0.01	0.05±0.01
W_9	0.04±0.00	0.214	nd	0.93±0.07	0.03±0.00	nd
W_{10}	0.16±0.02	nd	nd	0.36±0.13	0.04±0.02	0.08±0.00

W_1-W_{10} represent water samples from different enterprises. *nd=not detected. The results of the heavy metals given in this table are the average of three independent. The current findings showing very low levels of evaluated heavy metals in water used for processing lead to suggestion that there could be other sources of heavy metals found in the processed pineapple products, such as pineapple fruits, soil where the pineapple fruits were grown and/or processing equipment.

for 30%; the nectar samples that had higher levels of yeasts and moulds than the permissible levels set by Rwanda Bureau of Standards and Codex Alimentarius Commission. The levels of heavy metal contamination for copper, iron and zinc in juices and lead in jams were within the permissible limits set by the Rwanda Bureau of Standards. However, the lead and cadmium levels were above the permissible limits in nectars and syrups while the levels of copper, zinc and cadmium were above the permissible levels in jams. Therefore, additional research is needed to establish the actual source of heavy metal contamination in pineapple processed products displayed in the open markets and different supermarkets in the country. While doing more research, there is also a need of considering the time of sample collection as the concentrations may depend on the time and season the samples were collected. The research will facilitate intervention to lower the levels in the products due to their health concerns. In addition, processors need to be informed on the requirements by local, regional and international markets so that they strive to comply with the set limits.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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