Materials Selection And Fabrication Practices For Food Processing Equipment Manufacturers In Uganda

John Baptist Kirabira, Martin Ssembatya, Andrew Ayor

Abstract: The food processing industry is one of the fast-growing sub-sectors in Uganda. The industry, which is majorly composed of medium and small scale firms, depends on the locally developed food processing equipment. Due to lack of effective materials selection practices employed by the equipment manufacturers, the materials normally selected for most designs are not the most appropriate ones hence compromising the quality of the equipment produced. This has not only led to poor quality food products due to contamination but could also turn out health hazardous to the consumers of the food products. This study involved the assessment of the current materials selection and fabrication procedures used by the food processing equipment manufacturers with a view of devising best practices that can be used to improve the quality of the food products processed by the locally fabricated equipment. Results of the study show that, designers' experience biasness and desire to minimize cost compromise the materials selection procedure. In addition to failing to choose the best material for a given application, most equipment manufacturers are commonly fabricating equipment with inadequate surface finish and improper weldments. This hinders the equipment's ability to meet food hygiene standards.

Key words: design, food processing equipment, food contamination, hygienic design, materials selection, product contact surface, small-scale industries

1 INTRODUCTION

UGANDA is an East African country with one of the fastest growing economies in the Sub – Saharan Africa, enhanced by booming agricultural production. Industrialisation is one of the major growing sectors of Uganda's economy. As quoted by Uganda Bureau of Statistics (UBOS), the country's average Annual GDP growth rate was 5.44% between the fiscal years 2010/2011 and 2014/2015, with the highest value registered as 9.7% in the year 2010/2011 [1]. The industrial manufacturing sector's contribution to the total country's GDP increased from 7.5% in 2006 to 8.3% 2010. Its contribution has risen to 20.4% by 2014/2015. The other major sector of the country's economy is agriculture. Agriculture contributed by 22.5% to the country's GDP in the fiscal year 2010/11 [1] & [2]. Agriculture's contribution to the GDP slightly increased to 24.7% by 2014/2015 [3]. It is projected that agriculture is to remain one of the major sectors for East African Countries, Uganda inclusive, in the medium term [4]. Worth noting is that the agricultural sector employs about 70% of the country's population albeit its contribution towards the country's GDP declining from 46.4% in 1990/91 to 24.7% by the fiscal year 2014/2015. The flourishing agricultural sector has attracted many small and medium firms to add value to a variety of agro-produce.

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This has also encouraged many enterprises to develop appropriate technologies for processing the farm outputs. Improving the output of the agriculture sector, reduction of the post – harvest losses through improving food processing is very crucial. This is the main reason why the food processing industry, including both small scale and medium scale, is playing a huge role in the country's rate of industrialization. Food processing is a resource-based sector of the economy of strategic importance to industrial growth. In developing countries, it comprises of 20% of all manufacturing activity and represents about 60% of the value added by all industries which process agricultural raw materials [4]. In a country like Uganda, small-scale food processing industrial related activities are socioeconomically desirable investments because as labour-intensive units, they offer high employment opportunities. However, there is need for appropriate equipment which can be able to achieve not only the necessary productivity but also quality and hygiene standard food products to achieve competitiveness. Products from the country's agriculture sector include farm produce, livestock, and fish products. Among the commonest harvests – produce that require postharvest processing in the country include maize, beans, bananas, cassava, sweet potatoes and Irish potatoes. The national yields of these crops are 4 million Mt, 2.9 million Mt, 1.8 million Mt, 154, 000 Mt, and 23,000 Mt respectively [5]. Other crops worth mentioning include; Rice, Sorghum, Finger millet, Cow peas, Ground nuts, mangoes and oranges. The food processing industry, which is dominated by medium and small scale firms, mainly depends on locally designed and fabricated equipment. In Uganda, the small-scale metal fabrication sector has demonstrated creativity and innovations in development of appropriate technology for food processing. Additionally, the same sector endured and was able to maintain the industrial sector operational during the periods of economic recession (in the 1970's to 1990) than the large enterprises because their production technology tends to be less import dependent. The same sector has manifested a greater ingenuity with regard to technological adoption and transfer and substitution of local materials for imported inputs. In other words, if this sector is well supported, in the long term, associated activities in product design and development as well as the manufacture of equipment can be generated and could be a strong support for the agricultural sector. If well guided, with its stimulating effects on agriculture, manufacturing food equipment locally would contribute to a balanced, meaningful and sustained economic growth. There is a vast number of materials from which machine designers have a task of choosing the most appropriate for construction of a given design. This number is quoted to be close to 120,000 [6]. A designer must use an effective procedure and methods in order to achieve at the most appropriate material candidate for any given design. No single material can fulfil all functional and performance requirements of any design. In choosing materials, a compromise of some requirements e.g. strength, elasticity, corrosion resistance among others has to be taken apart from the primary requirements of the design like inertness to service conditions. Even though use of experience regarding the performance of different material for a given performance requirement is a necessity; a designer must accompany this by use of different sources of materials information in order not to eliminate the possibility of material substitution. As suggested by Ashby [6] and Cheremisinoff [7], the procedure illustrated in Figure 1 should be adopted while selecting a material for a design with multiple constraints. This procedure involves assigning a weighting factor to the different design goals of the material. A material that maximizes the high importance goals is ranked as the best. It is important to note the failure analysis step of the selection procedure. There are a number of suggested methods that can be used to narrow down the materials list from which the final candidate must be chosen. These include; Limits on material properties – which involves use of rigid and relative requirements, cost per unit method – which involves determining the cost required to achieve a unit of the desired material property, the Ashby's method which involves use of materials selection charts, and the weighted – properties method – which involves assigning each property a certain weight depending on the importance to the performance of the part in service. During the design of most food processing equipment, there are a number of functional requirements the chosen material must fulfil. The most important objectives in this case include achieving of food – material compatibility in the design and prevention of the food material microbial contamination of food products. In most cases, such contamination originates from the food raw materials, but also the product can be contaminated with microorganisms during processing and packaging. If the original equipment design was default of hygiene design, then it will be difficult to clean because residues may be retained in crevices and dead areas, permitting microorganisms which they refuge to survive and multiply. In any product development project the major aim is to achieve an equipment that fulfils its engineering function. However, specifically for food processing equipment, the requirement for hygiene is often conflicted with. Whilst, in seeking any acceptable compromise it is imperative that food safety is never compromised to this kind of risk. The criteria for hygiene design of food contact surfaces should ensure that the surfaces are smooth, impervious, free of cracks and crevices, nonporous, non-absorbent, non-contaminating, nonreactive, corrosion resistant, durable and maintenance free, nontoxic and cleanable [8], [9], and [10]. If the surface is coated with metal alloy, ceramics, plastic, or rubber in any way, the final surface must meet the previous criteria but also the 3A hygiene standards. The 3A standards require that such coatings maintain corrosion resistance, and be free from surface delamination, pitting, flaking, chipping, blistering, and distortion under conditions of intended use. Similarly, if any modifications or process is used in fabrication it should be done using appropriate materials and in a manner that ensures the final surface meets the hygiene design criteria.

TABLE 1: *AISI, DIN AND EN DESIGNATIONS OF STAINLESS STEELS FOR FOOD EQUIPMENT [10]*

AISI	DIN/EN	Typical analyses					
		C%	Cr %	Ni %	Mo %	Ti%	N%
304 L	e.g. DIN 1.4307 (EN X2CrNi 18-9)	<0.03	18	9	-	-	-
316 L	e.g. DIN 1.4435 (EN X2CrNiMo 18-14-3)	<0.03	18	14	3	-	-
410	DIN 1.4006 (EN X12Cr13)	<0.12	13	<0.75	-	-	-
409	DIN 1.4512 (EN X2CrTi12)	<0.03	11.5	-	-	<0.65	-
329	DIN 1.4460 (EN X3CrNiMoN27-5-2)	<0.05	27	5.5	1.7	-	<0.20

In the materials selection process, a variety of materials is available for fabrication of different food equipment. However, their properties also vary in terms of compatibility, workability, and related hygiene features. Among these, stainless steel takes the biggest share in food equipment design because of its corrosion resistance and durability in most food applications. It should also be noted that not all stainless steel is food grade steel. The AISI, DIN and EN designation of stainless steels commonly used in the food industry are given in Table 1. Other food equipment materials include polymeric materials, elastomers (especially for seals, gaskets and joint rings), adhesives in gaskets, lubricants (should not be in contact with food), thermal insulation materials, and signal transfer fluids (which must be food grade). The objective of this work was to assess the quality of Ugandan, locally fabricated food processing equipment with a view to ascertain challenges faced by the fabricators and seek insights for improving the sector.

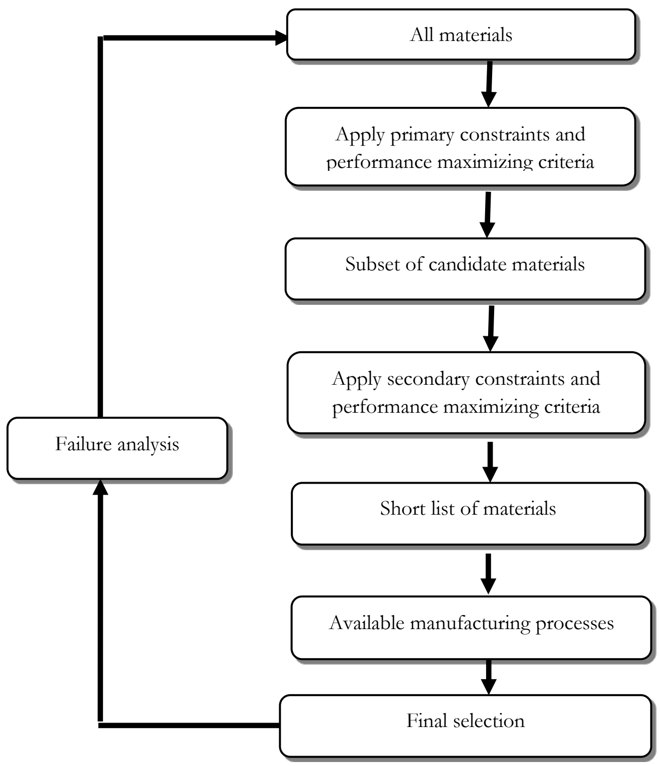

Figure 1: *The Cheremisinoff materials selection procedure flow chart [7]*

2 METHODS

The study was mainly focused on the wet/moist food materials processing equipment like fruit juice extractors, oil presses, ground – peanut butter machines among others. The material selection procedures and materials used for the purpose of construction of the equipment were identified through interviews ad observation. The employed materials selection practices and procedures were compared to the standard practices. The study surveyed forty food processing equipment manufacturers in the areas of Kisenyi, Katwe, Kawempe, Bwaise, Ndeeba, Bweyogere and Kanyanya. All these are found in Kampala District in Central Uganda where the highest number of food processers operate from. Various industrial visits were carried out to these firms and this enabled carrying out personal interviews with the companies' artisans and directors who are involved in the design and development of the different food processing equipment. Questions were asked during these interviews that enabled gathering information that could help attain the research objectives. Observations of the different products and activities at the firm level were also exploited and photographs taken to keep these records. The questions asked were based on the decisions made under eight categories, namely; constraints, reliability, functional requirements, resistance to service conditions, processability, cost of materials, and availability of materials on market, skills and knowledge of usage.

3 RESULTS, FINDINGS AND DISCUSSION

The results and findings from the survey were based mainly on the criteria used in materials selection, fabrication practices, hygiene requirements in relation to the required standard guidelines and the focus was on surfaces, joints, piping, seals and related installation to meet food contact requirements for the equipment.

3.1 Profile of fabricators, technology employed, skills and clientele

Most of the food equipment fabricators are small and medium scale firms, employing between 4 to 12 workers. They employ capital investments ranging from US $ 5,000 to over US $ 40,000 in machinery and general business operations. From the surveyed firms, the education qualifications/skills of the workers range from on-the-job training (20%); artisans i.e. with equivalent of a master craftsman certificate (38%), technicians (40%) and 2 % had higher degrees to master's level. 90% of the owners of the firms surveyed had previously worked for or been involved in similar trades of food processing equipment. A couple of the business owners had attained certificates and degrees in business and management skills through training. The equipment owned by the firms were mainly the ordinary tools and equipment used in conventional metal fabrication workshops. It should also be noted here that these fabricators were not only manufacturing food processing equipment but also ordinary metal products for the construction industry, furniture and related industrial parts and equipment. Equipment installed include ordinary arc-welding machines / generators, bending machines, rollers, angle and pedestal grinders, TIG/MIG welders and a number of assorted tools. Some had all the essential tools needed in fabrication of food equipment while others had only the basic fabrication equipment and could not afford specialized equipment like those required in welding of stainless steel. The product equipment in the area of food processing manufactured by the firms surveyed included pans, popcorn makers, peanut butter makers, grain milling and huller machines, milk and juice pasteurizers, juice extractors, oil mills, cassava and potato chippers, boilers, deep fryers, cereal roasters, food/meat extruders, food storage chambers, food packaging and sealing machines, bakery troughs, kneading and dough machines, mixers and blending machines and many others. The main clientele of these firms included domestic or individual customers, food processing firms, institutions (like schools, churches, hospitals, research facilities, NGOs) and most of them were local (88%) and the rest came from the region (Rwanda, Burundi, DRC, Tanzania, Kenya, and Southern Sudan).

3.2 Practices used to determine the final materials selection

The survey involved over 40 food equipment fabricators, and the summary of the factors that determine usage for particular materials for a required equipment is as in Figure 2.

3.2.1 Performance requirements considered by designers

Designers normally consider a number of performance requirements during materials selection and these include; resistance to service conditions i.e. resistance to attack by the food material and/or environment intended to be handled by the equipment, cost requirement which involves designing for optimization of the overall design cost, processability which is the ease with which the machine component can be manufactured when made out of a given material. Considered are also functional requirements of the design which are the primary requirements a design must fulfil. It was noted that cost is a major factor considered by manufacturers during design. This prejudices the effectiveness of the materials selection procedure because it is very likely to bias the selection leading to a less effective and cheaper material.

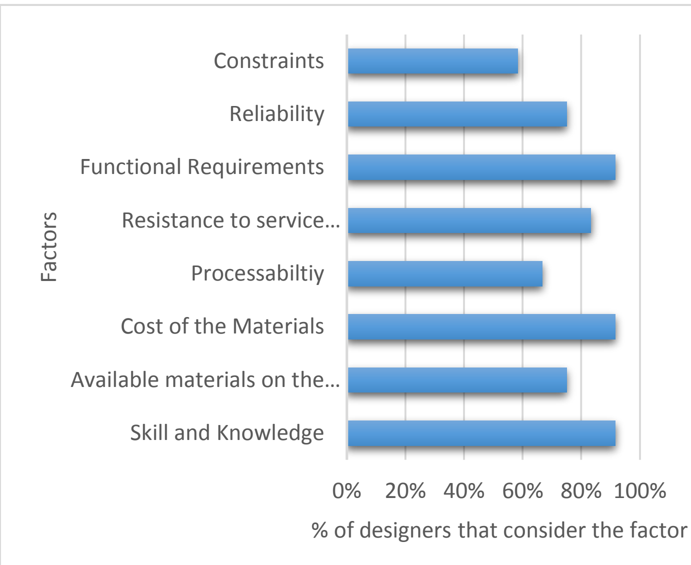

Figure 2: *Basis on which final materials selection is determined by fabricators*

3.2.2 Construction materials and toxicity minimization

It should be noted that materials used in the fabrication of food processing equipment must fulfil specific requirements such that product contact material or surface is inert to the product under any operating conditions as well as to cleaning detergents and sanitizers. Basically, the material in contact with the food product must be corrosion resistant, smooth textured, nontoxic, mechanically stable, and easily cleanable. However, from the survey it was evident that most of the firms' selections do not conform to the mentioned minimum standard requirements for construction materials. Findings indicate that only 2 out of the 40 fabricators selected the suitable food grade materials for construction of food equipment. The rest of the firms selected nonconforming materials like mild steel (for instance in construction of peanut butter grinding machines), galvanized steel (in juice extractors), uncoated aluminum containers (for fruit juices) and some would instead use stainless steel (with 10% Cr) which is also not food grade. Despite the fact that some fabricators have skills to follow the right procedure to come up with the appropriate materials, this weakness was attributed to:

- Minimizing the final cost of the equipment
- Limited availability of the appropriate materials on the local market and related costs
- High cost of purchasing and subsequent processability of the material.
- Unhealthy business competition leading to pressure on fabricators to try completing contracts as fast as possible yet compromising the appropriate practices.

Other than the general stainless steel types (AISI-304, AISI-316 or AISI-316L) that are widely used for food grade surfaces because they offer sufficient corrosion protection, plastics and elastomers can also be used. However, during the survey none of the group surveyed used plastics in the fabrication of food equipment. Also worth mentioning is that a host of fabricators use scrap plates, piping, and related part without critical scrutiny of the scrap, cleaning and determination of material grade. This could also introduce toxicity in the subsequent application of the equipment.

3.2.3 Materials selection procedure currently employed

Based on the interviews with the designers, food processing equipment manufacturers normally apply the materials selection procedure that is evident to have a number of deviances from the standard procedures suggested in [6], [7], [8], [9] and [10]. First, the full menu list of materials from which to choose is mainly generated based on the designers' experience i.e. basing on knowledge of performance of materials used for a similar application in the previous designs. This method does not only eliminate the possibility of material substitution for a given material application since it doesn't enable assessment of novel materials for a given application but it also kills creativity. Secondly, during the screening stage, factors such as environment protection, material's durability during use are not common key factors that are used to narrow down the materials options generated in the first step of the selection procedure. Thirdly, cost plays a very big role towards the kind of final material option chosen. As noted earlier cost based - material selection has various limitations. Lastly, and most importantly, it is observed that the conventional material selection procedure doesn't encompass the failure analysis step as the Cheremisinoff – procedure, Figure 1, of the chosen material. This is such an important step that shouldn't be ignored. It enables ascertaining if the chosen material is the most appropriate material candidate. Sometimes, testing of the material or machine and/or machine component (either experimentally or by modelling) should be done in the service environment of the machine design. All this is not done by the food processing manufacturers. Sometimes, testing is only used to ascertain the material procured for use in design. In this case, experience based verification which involves use of one's experience to judge the material's performance and Magnetism test which is commonly used to test if the material is stainless steel in nature are used. The latter test has a limitation that it's not only stainless steel that is a nonmagnetic engineering material.

TABLE 2: *COMPARISON OF THE CURRENT AND THE MOST APPROPRIATE MATERIALS SELECTION PROCEDURE*

Materials selection procedure step	Standard selection procedure [7], [8]	Currently used materials selection procedure
Generation of initial materials menu	✓ Should consider all possible options ✓ Should be generated using a well stored source of data about materials performance e.g. Computer materials databases	✓ Not all possible materials options are considered ✓ Based on designer's knowledge of the materials performance in similar previous designs
Initial screening	✓ Involves narrowing down list of materials using rigid requirements and geometric restrictions ✓ Commonest methods suggested are Ashby's method, cost per unit method, and limits on materials method.	✓ Not commonly done due to a narrow initial material options list generated ✓ If done, cost minimisation and consideration of the go/no – go requirements are used.
Final selection	✓ Weighting factors method and comparison to the local needs and expertise used to choose the material that best fulfils all performance requirements	✓ The two commonest performance requirements used to aid the final selection are cost and functional requirements

It is also interesting to note that a good number of firms fabricate food processing equipment without following any materials selections procedure, but just copy from other designs and fabricate according to the order given. Table 2 gives a summary of the comparison between the suggested appropriate materials selection procedure (Cheremisinoff – procedure) and the commonly used procedure used by the designers.

3.3 Functional Requirements

From the survey finding indicate that 36 out of the 40 firms fabricated equipment that meet engineering functionality requirements. However, it should be noted that for food equipment functionality design differs from the conventional ones. The approach emphasizes hygiene aspects as a must to be integrated to achieve good overall functional requirements. The following were noted in the designs surveyed:

3.3.1 Cleanability and decontamination

Besides choosing nonconforming food grade materials among the 38 firms, mentioned in 3.2.2, the equipment were found difficult to clean, difficult to dismantle for repair and maintenance and were prone to contamination by aggressive detergents.

3.3.2 Prevention of ingress and growth of microorganisms

Food equipment must maintain an environment limited of organisms as much as possible in order to meet the product shelf life and also mitigate public health requirements. Unfortunately, most of the locally fabricated equipment had construction and fitting weaknesses leading to dead ends, crevices, and gaps in joints. These defects were common to presses, peanut butter making machines, cereal grinding mills, dairy storage and processors, and juice extractors. These lead to settlement of product remains and trap microorganisms which could subsequently multiply and contaminate the equipment.

3.4 Hygienic design requirements

For hygiene design, food equipment must have food contact surfaces which are as smooth as possible. The requirement dictates that during use, the surface in contact with food must be nontoxic, non-absorbent and resistant to product as well as to cleaning and sanitizers. According to EHEDG, 2004, surfaces must drain (slope ≥3°), a roughness Ra ≤0.8 μm and avoid misalignment, crevices, screw threads, sharp corners (r ≥ 3 mm) and no dead areas. Similar studies reveal that that poor hygiene of equipment is one of the most serious problems in the food industry; nevertheless there is still little awareness of possible consequences of equipment that is not hygienically designed [10], [11], and [12].

3.4.1 Surfaces and geometry

The survey finding indicate that over 80% of the food equipment inspected had crevices, metal-to-metal joints made with either rivets or screws, poor drainage with slopes horizontally oriented and others more than 3°, poor gaskets, dead ends, and corners made out of scrap materials at 90°.

3.4.2 Drainability and layout

All guidelines on food equipment design contend that the exterior, interior and pipework of food equipment must be self-draining as well as easily cleanable. Hence the design requirements must avoid horizontal surfaces and adopt slanting ones instead. This practice has been followed by over 98% of the local fabricators that were involved in the survey of this study.

3.5 Fabrication practices

3.5.1 Surface finish

To minimize food product contamination, food processing equipment components, especially those surfaces in contact with food must have a surface finish or smoothness that is free from imperfections such as pits, folds, and crevices. A good surface finish ensures no food materials is retained in the equipment to minimize growth of microorganisms. A surface finish Ra = 0.8 μm is recommended by EHEDG [10]. It was noted in the survey that the smoothening of the food contact surfaces were done poorly and actually in most cases fabricators were not bothered about smoothening the surfaces. Only very few equipment were found to have been fabricated to a satisfactory smooth surface finish. A typical equipment with a satisfactory good surface finish is illustrated in Figure 3. However, for most equipment fabricated, a lot of imperfections like pits, folds, misalignments, were noted as can be shown in Figures 4 and 5. Only two out of the forty fabricators were able to achieve the required food grade surface finish and free of imperfections.

Figure 3: *Equipment with a fairly satisfactory surface finish as compared to products of other fabricators*

Fabricators attributed this to mainly two challenges: firstly, is lack of the equipment to smoothen the stainless-steel materials and also being able to measure the achieved surface finish. The second reason was that they were ignorant of the minimum surface finish requirements for food contact surfaces.

3.5.2 Weldments

Of the surveyed fabricators, only two out of the forty could carry out proper welding to achieve acceptable weldments as required for food contact surfaces. The rest of the welders could not achieve the required weldments. As can be shown in Figure 3, a good weld achieved by one of the fabricators in the first group is indicated. However, the weldments from most other groups were characterized by imperfections that lead to surface weakness and subsequently act as sources of microbiological problems via inadequate cleaning and drainage and hence product retention. As illustrated in Figures 4 and 5, the key observations in these weldments are:

a) Lack of weldment penetration or incorrect penetration also known as under penetration, hence creating crevices that subsequently trap food materials at the joint, see Figure 5. This was identified as one of the major hygienic problems both in containers and pipework.
b) Due to poor workmanship, weld joints which are rough and poor especially in the heat-affected-zone. This problem was attributed to inadequate inert gas shielding due to lack of proper skills by the workers.
c) Again, due to poor skills, misalignment was noted in various cases. This was attributed to several causes, ranging from incorrect fitting, improper design implementation, to mismatch in thickness and/or diameters in case of pipefittings.
d) Some fabricators use ordinary arc welding when making joints of stainless steel plates/cylinders. This would lead to very rough joints and worst of all centreline cracking of the weldment. Subsequently, food materials lodges into these cracks leading to microorganism growth and sometimes leakage and soiling of the equipment. Another problem related to this was lack of full fusion of the weld metal to make a firm joint with the parent metal plate. This would again result into crevice formation at the interface between the weld and parent metal. It should be noted that many welding processes are commonly used in joining steel, but only a few can achieve welds of hygiene quality free from the defect indicted in this section. The appropriate welding process for joining stainless steel for food equipment is the Tungsten Inert Gas, also commonly known as TIG. The other advantage of TIG is that a high-quality surface roughness of $R_a = 3 – 4$ µm can be achieved.

As it can be noted, most of the local equipment were constructed with poor weldments that contravenes the appropriate standards as quoted in [10], [11] and [13].

3.6 Regulations and Standards

In Uganda, the Uganda National Bureau of Standards, UNBS, is responsible for all quality and standard of products made and also imported into the country. A review of the current operations of UNBS indicate that the practice in food safety has been properly regulated in terms of the quality and safety of packed foods, juices and related consumable products. However, it should be noted that, UNBS has not yet developed standards for hygiene fabrication, construction and design of food processing equipment. It is therefore essential, in the meantime, for practitioners in this trade to borrow the existing standards and regulations from EHEDG [10], Sanitary Standards, Inc. (www.3.a.org), the National Sanitary Foundation, (NSF) (www.nsf.org), and Underwriters Laboratories (www.ul.org), which are internationally recognized and involved in the development of food equipment standards as well.

Figure 4: *Improper surface finish [Outside view]*

3.7 Some food processing equipment cases

Some cases of food processing equipment manufactured in Uganda were taken to illustrate some of the flaws made in choice of component materials and fabrication practices.

3.7.1 Manual cassava chipper

Figure 6 illustrates the Manual cassava chipper produced by one of the food processing manufacturers in Kanyanya. The chipping plate is in direct contact with the wet cassava material. This component is made of Aluminum, however, as noted earlier, stainless of food contact grade would have been a better option for this purpose. The former material is chosen because it is more available, cheaper and easily given the chipping plate's shape than stainless steel.

3.7.2 Maize threshing machine

Figure 7 shows the salient parts of a Maize shelling machine manufactured by one of the manufacturers. It is observed that all the major components of the machine are made of mild steel, threshing shaft inclusive. As it can be observed from Figure 4, after some time of operation, the mild steel threshing shaft that is in direct contact with the food material (maize) has undergone rusting (uniform attack corrosion) due to the moisture content of the maize. This impairs the quality of the maize seeds produced by the machine. A more corrosion resistant material would be better for this machine component (threshing shaft).

Figure 5: *Improper surface finish [Inside view]*

Figure 6: *Manual cassava chipper*

3.7.3 Banana juice extractor

This machine is designed to extract juice out of the ripe banana fruits that are locally grown and harvested. Figures 8 and 9 illustrates the salient features of this machine. It can be noted that the juice collection pan is constructed from aluminum and the extraction impeller is constructed from Low Carbon Steel. However, as noted earlier, aluminum does not represent the best choice of material for the pan. Furthermore, it is so alarming that the impeller is constructed from such a nonfood grade material. Low Carbon Steel is prone to corrosion from the juice which compromises the quality of juice produced by the machine. The surface finish of the impeller is also not sufficient as can be seen in Figure 8.

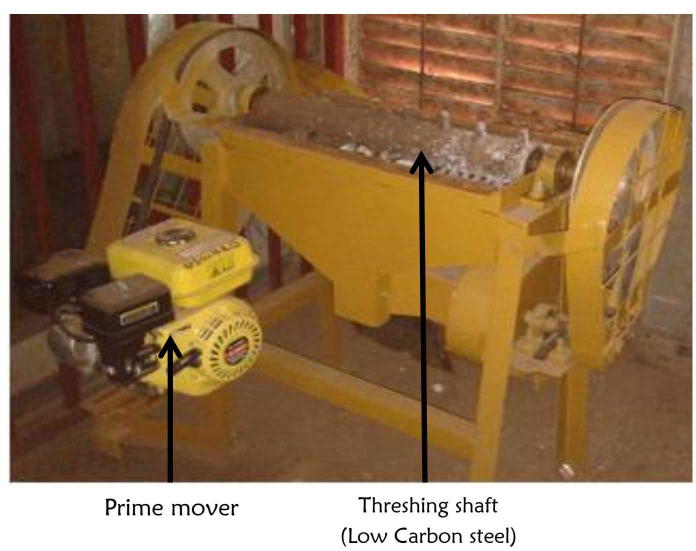

Figure 7: *Maize threshing machine*

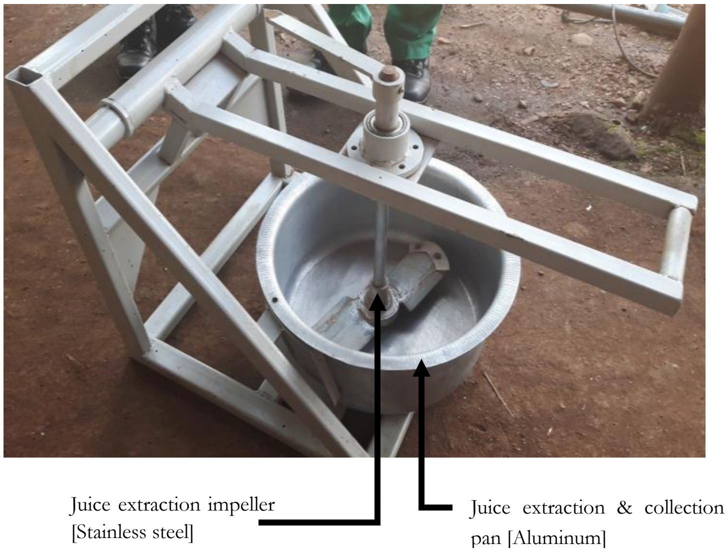

***Figure 7:** Banana juice extractor*

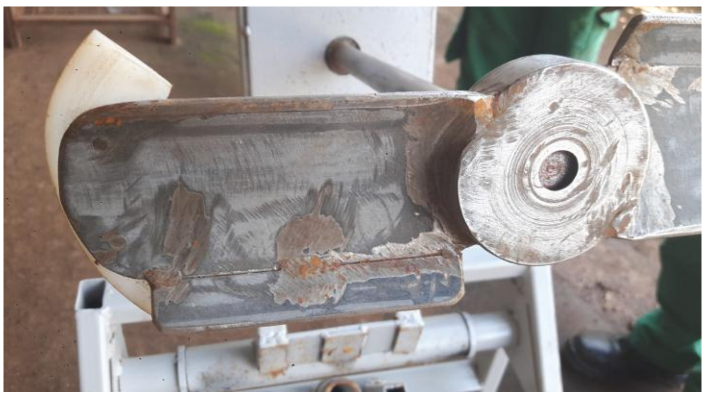

***Figure 8**: Banana juice extractor [Bottom view of the extraction impeller]. The materials used is neither food grade nor stainless steel. Corrosion is evident and a vast manifestation of crevices, poor surface finish and weldment.*

4 Conclusions

It was observed that to a very large extent, the industries use similar methods for material selection for their designs. The major causes of improper materials selection were identified as; use of less effective selection methods, motive to use less costly materials, and lack of some more effective materials in the required forms in the country. The major issues identified in the conventional process of materials selection was the failure to analyze all the performance aspects of the equipment designed, and lack of necessary information on all possible materials options from which the best must be chosen. The results of this study offer a wide overview on how the materials selection and fabrication practices employed by food processing equipment designers and manufacturers in Uganda can be improved. It should be noted that individual countries can benefit from fabrication and maintenance of their equipment. This is particularly important for especially developing countries whose economy is based on agriculture. Improving productivity of food processing systems means an increase in food availability at a reasonable cost, and indirectly improvement in the standards of living. This means that a number of food products can be made from produce, hence adding value as well as preserving the food and subsequently contributing to food security. However, the study notes that even though lot of effort has been done on an individual/private basis, with some success in terms of products meeting the required standards, the biggest number are failing. Hence there is need to emphasize to the local fabricators the following in order not only to meet the required standards but also to improve productivity to enhance competitiveness especially from imported food processing equipment and food products:

- Proper selection of materials and the related appropriate welding process. Contamination is minimized – surfaces, in particular those in contact with food, are smooth and continuous, non-corrosive, non-toxic, in intended use and where necessary, suitably durable, and easy to clean and maintain.
- Materials that are not food grade should avoided at all costs.
- Design and layout permit appropriate cleaning, maintenance and disinfection.
- Improvement of product design and development skills
- Improve fitting and assembly skills.
- Adoption of the existing international acceptable food equipment standards and guidelines.

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