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RESEARCH ARTICLE

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Potential Economic Importance of Agave Plants in Kenya: A Special Focus on Alcohol Production

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Abstract

Large tracts of land in Kenya are arid and semi-arid making them agriculturally unproductive. They are synonymous with endemic famines and can be considered a liability to Kenya's economy. The succulent Agave plants, which are adapted to these zones, have several industrial purposes. To date, they have remained largely under-exploited in Kenya. Mexico is the world leading producer of Tequila; an alcoholic beverage obtained from agave plant. A detailed review was done on the production of distilled beverage from agave plants. Brief reviews were also done on other potential uses of the plant and the requirements of the agave plant cultivation. Possible bottlenecks in the production of distilled beverages from agave plants have also been highlighted. This aims to compel potential investors, especially in the beverage industries, to consider tapping into the possible fortunes of agave cultivation.

Keywords: Agave Plants, Agave Spirit, Distilleries, Mexico, Kenya

INTRODUCTION

Agave spp are Crassulacean Acid Metabolism (CAM) plants and therefore adapt in the arid and semi-arid environments (Owen *et al*., 2016). The genus *Agave* is the largest one in the family Agavaceae (Garcia, 1988). They are hardy plants with thorns along the edges of the leaves. They have a growth lifespan of 8-12 years depending on the soil and climate (Arizaga & Ezcurra, 2002). The plant has very many uses, some of which are economically viable.

In Kenya, it is commonly grown for their aesthetic value (Figure 2). Commercially, *Agave sisaliana* is grown at the coastal region of Kenya for sisal fibre production. In some regions of the country, it is used for medicinal purposes (Njoroge *et al*., 2010; Okello *et al*., 2010). In Mexico, agave plants play a critical role in agroindustry where distilled beverage called tequila is produced from *Agave tequiliana*. The product is protected by appellation of origin (Lisbon Agreement, 2016). Therefore, tequila can only be produced from the agave plants grown from specific parts of Mexico (Figure 1). If similar drinks are produced elsewhere in the world, they would not be referred as tequila. In Mexico itself, there are agave spirits produced in other regions due to oversupply of agave; those drinks are called distillates or 'aguardientes' (Valenzuela, 2011). Other countries where the agave spirits are produced include South Africa and India. *Agave americana* is the agave species of choice in South Africa (Boguslavsky *et al*., 2007). Mescal is another distilled beverage from agave mainly from *Agave angustifolia* (Pérez-Pimienta *et al*., 2017). Other non-distilled beverages include *aguamiel* (sweet drink) and fermented pulque (Nobel, 1998).

Different species of the plant therefore, produces varied kinds of drinks. Further, a specific species has in itself the potential to produce at least five different sorts of drinks. This venture holds vast promise of widening the brands of beverage produced by an enterprise willing to take it up. Further, barley which is the conventional raw material in most all Kenyan beer industries, is more susceptible to the effects of climate change. *Agave* spp. are more stable with volatile climate and can also be cultivated in areas with rugged terrain. Kenyan beverage industry players (example, Keroche and East African breweries) should really consider tapping into the Kenya's potential to cultivate agave plants for the production of beverages.

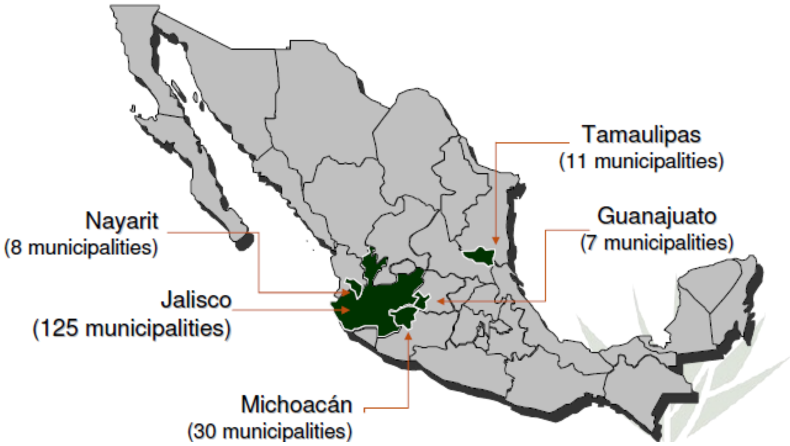

Figure 1: The Regions in Mexico where *Agave tequiliana* used in the industrial production of tequila is grown.
Source: Tequila Regulatory Council, 2010

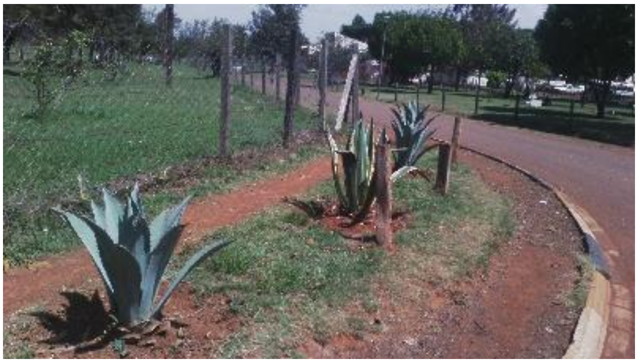

Figure 2: Agave plants used for their aesthetic value.

Importance of Kenya's Involvement in Production of Spirits from Agave

Large fraction of Kenya's landmass (88%) experiences arid and semiarid conditions and home to a quarter of the country's population (Wandago & Chemonges, 2006). These regions (northern Kenya, eastern and coastal regions) are hence important in supporting rural populations (Shisanya, 1996). They are however characterized by frequent droughts and famines resulting in mortality of humans and livestock. On the episodes of hunger pangs, the immediate suggestion to solution is the need for irrigation. Even if that happened, a large proportion of this dry landmass would still remain barren. Globally, the dry lands have been associated with mineral deposits and almost always the only way they contribute to the growth of economies. Such prospects blind us to the immense economic potential hidden in these lands. This is particularly so for Kenya where unfortunately, not much of mineral reserves have been found in these areas. Due to scarcity of resources, these are the most conflict prone zones of Kenya. These occurrences derail Kenya's economic progress impeding her from achieving the envisioned future state, that of being a middle-income economy by the year 2030. As a way to unlocking the economic potential of ASAL areas in Kenya, drought resistant cash crop farming is suggested in this paper.

Cultivation of agave plants for industrial purposes offers a viable option to make this vast region economically productive. It was for the same purpose that agave cultivation was introduced in the arid great Karoo region of South Africa (Boguslavsky *et al.*, 2007; Ganduri *et al.*, 2015). This mode of livelihood improvement is regenerative (non-extractive) (Ngugi & Nyariki, 2005) and hence ecologically sustainable. Further, the worldwide demand of agave spirit is yet to be met (Boguslavsky *et al.*, 2007). Kenya should therefore seek to fill this gap. Further, other potential uses of agave plant include source of fructans from inulin, production of first-generation biofuels, production of fibres and papers etc. From an economical point of view, the alternative uses of the plant can only be feasible when the agave plant is used primarily on industrial scale. Here we have briefly reviewed the requirements for cultivation of agave, reviewed in great detail the production of agave spirit (tequila model) and also reviewed other potential uses of the plant.

Ecological Factors Required for the Cultivation of Agave Plants

Agave spp grow on poor quality rocky soils in regions with extreme drought and high temperatures (Davis *et al.*, 2011). It however grows in well drained loamy soils (Sisal Production guideline, 2015). Optimum growth can be achieved with annual rainfall of 102-127 cm, but high yields have also been observed in regions with 25-38 cm annual rainfall (Kirby, 1963). Propagation of the plant is done by two main mechanisms: Use of seed which resulted from sexual reproduction or apomictic seeds and Vegetative reproduction using offshoots from the mother plant (Arizaga & Ezcurra, 2002).

Vegetative reproduction is the primary means where the shoots are cut form 4-6 year old plants (Sisal Production guideline, 2015). Shoots from the agave plants younger than 4 years and older than 7 years are of poor quality. The young agave plants are then transplanted into 30 cm deep furrows. When grown in arid areas, planting should be done on rainy seasons (Garcia-Moya *et al.*, 2011). Growth nutritional requirements vary with different stages of the plant's life. Peat pots supplemented with slow release of calcium and magnesium are used for nursery plants (Davis *et al.*, 2011). In the field, a supplemental nutrient solution is applied. A mixture of nitrogen, phosphorus in form of P_2O_5, potassium in the form of K_2O, boron, copper, and zinc (40: 120: 40: 4: 2.5: 16) are applied in the first year and 40: 80: 80: 4: 2.5: 16 in the second year (Uvalle & Vélez, 2007). In the third year the nutrient amendment is then limited to nitrogen, phosphorus, and potassium (60: 40: 80) and only nitrogen in the following years (Uvalle & Vélez, 2007).

Harvesting of Agave Plants

The agave plants are harvested when they mature at 8 years but sometimes 12 years (Valenzuela-Zapata, 1985). The agave plant is harvested by removing the leaves leaving an elliptical heart or head resembling a huge pine-apple (fig 3; a & b). The agave heads are then transported to the distillery for processing (fig 3b).

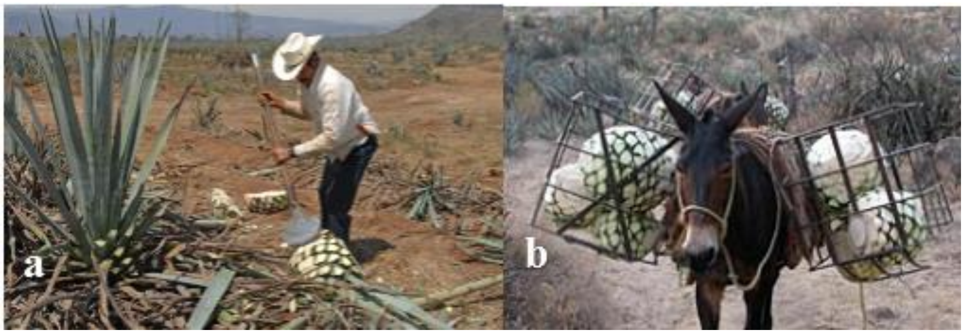

Figure 3: a) Harvesting of agave plants; b) Transporting the agave heads.
Retrieved from: http://www.tequilasource.com/tresmujeres/pics/jimador-tres-mujeres_361_r2.jpg.

Stages in the Production of Agave Spirit (Tequila Model)

In preparation for industrial processes, the heads are halved or quartered (fig 4a). This preliminary activity may either take place in the agave field or within the distillery.

The Industrial Processes

The summary of industrial production of agave spirit includes four steps; cooking and juice extraction, fermentation, double distillation and bottling. In tequila industry, this bottled product is known as tequila *blanco*. Maturation can still take place and depending on the period of maturation different flavors of the spirit can be obtained.

Cooking and Juice Extraction

Once the heads arrive to the factory they are halved and loaded by hand to the cooking furnace. Cooking takes place either in traditional ovens or in stainless steel (Valenzuela-Zapata, 1985). Steam is used to avoid dehydrating the agave. Cooking takes place for 12 hours in stainless steel and 24 hours in traditional ovens (Cedeño, 1995; Valenzuela-Zapata, 1985). In South Africa some brands of agave spirits are made by cooking the heads for 3 days with lava rocks which gives it unique flavor (Laubster, 2017). Cooking assists in hydrolyzing of inulin into fructose and glucose (Cedeño, 1995; Valenzuela-Zapata, 1985). Inulin refers to a polydisperse chain of fructose units with degree of polymerization varying from 2-60 (Boguslavsky *et al.*, 2007). During this step, part of the vapour condenses and begins to extract sugars from the agave heads by diffusion producing a sweet juice known as 'cooking honey' (Waleckx *et al.*, 2008). The flavor of the final product is determined by oxidation and dehydration of sugar products generated at this stage (Lamas-Robles *et al*., 2004).

The cooked agave is macerated and transported on conveyor belts to shallow porous tanks. This shredded material is then washed with portable water under pressure to dissolve the sugars (Valenzuela-Zapata, 1985). It is further pressed by a 2 ton wheel (fig 4 b & c) to extract the second juice known as 'agave juice' (Waleckx *et al*., 2008). At this stage the first industrial waste product, bagasse, is obtained. It however has more potential uses as fuel.

Figure 4: a) Halved agave heads in readiness for cooking in the oven; b) A cylindrical empty pressing bay [This is a traditional one where the wheel was driven by the help of oxen]; c) An ongoing pressing of the milled cooked agave heads to extract agave juice.
Source: Chadwick (2011)

Fermentation Process

The 'cooking honey' and 'agave juice' are then mixed and go to fermentation. The product of fermentation results in a beverage known as fermented pulque which can be taken as beer (Nobel, 1998). Fermentation is the important step in the production of agave spirit; a process which lasts approximately 72 hours. All distilled beverages are principally ethanol regardless of the source of fermentable sugar. But the difference between them is in the quantity and quality of secondary compounds produced especially during fermentation (Pinal, 1997; Amaya-Delgado *et al.*, 2013). This is what gives a particular spirit its characteristic organoleptic property. These secondary products include higher alcohols, esters, furfural and aldehydes. The organoleptic characteristics are impacted slightly by the source and type of fermentable sugar and greatly by the fermentation conditions (Pinal *et al*., 1997). Therefore for efficient fermentation, conditions such as temperature, pH, type of yeast, type and concentration of nutrient salts and enzymes and fermentation time and carbon nitrogen ratio (C/N) are controlled (Pinal *et al*., 1997; Arrizon & Gschaedler, 2002). Even within a particular species of yeast, difference in the organoleptic property has been observed among the different strains (Arellano *et al.*, 2008).

Traditionally, the wild diverse yeasts present on the agave surfaces were used in fermentation (Arellano *et al*., 2008). Reliance on wild yeasts for fermentation always produces beverages with inconsistent flavors. Currently, the most popular and perhaps the only yeast used in the fermentation of the must (mixture of 'cooking honey' and 'agave juice') is the *Saccharomyces cerevisiae* (Valenzuela-Zapata, 1985; Amaya-Delgado *et al*., 2013). There are other non-saccharomyces yeasts that have been found to be industrially viable with some being better in some aspects than Saccharomyces (Amaya-Delgado *et al*., 2013). These non-saccharomyces fermenters are the *Pichia kluyveri* and *Kluyveromyces marxianus* (Amaya-Delgado *et al*., 2013). In terms of ethanol yields, *P. kluyveri* has been found to produce the highest content while *K. marxianus* produces the least amount (Amaya-Delgado *et al*., 2013). *P. kluyveri* has been found to have the highest fermentation capacity making it suitable for use at the industrial level with production of high ethanol yields (Amaya-Delgado *et al*., 2013). Another equally important type of yeast, isolated from the agave juice is *Kloeckera apiculata* (Arellano *et al*., 2008).

With regard to C/N ratio, it has generally been observed that for most strains and types of yeasts low C/N levels result in low amounts of isoamyl alcohol as well as isobutyl alcohol production (Pinal *et al*., 1997). High C/N level means low nitrogen level which might increase deamination reactions of amino acids, leading to the synthesis of higher alcohols (Arellano *et al*., 2008). Lower nitrogen levels however can be a cause of concern since it impedes growth of the fermenting yeasts and hence efficiency of fermentation. This problem is compounded in agave spirit production since in the cooking step most assimilable nitrogen is degraded by heat (Arrizon & Gschaedler, 2002). The must therefore has low nitrogen levels needed during fermentation by the yeasts. To increase fermentation efficiency, this problem is circumvented by addition of a mixture of amino acids and ammonium sulphate as supplemental sources of nitrogen (Arrizon & Gschaedler, 2002). This is done only during the exponential phase of yeast growth during fermentation (Arrizon & Gschaedler, 2002). More higher-alcohols are also produced when the sugar level reduces as fermentation proceeds. This is a consequence amino acid metabolism (Arellano *et al*., 2008).

Another factor with significant effect on higher alcohol production is temperature (Pinal *et al*., 1997). It was demonstrated by Pinal *et al*. (1997) that more higher alcohols are produced at 35^0C than at 30^0C.

With regard to ester production, it has been found that *K. marxianus* produces more ethyl acetate than the popular Saccharomyces yeast strains (Amaya-Delgado *et al*., 2013). On the other hand, *P. kluyveri* has the capacity to produce more ethyl lactate than *Saccharomyces* (Amaya-Delgado *et al*., 2013). Generally in the experiments by Amaya-Delgado *et al*. (2013) the non-Saccharomyces yeasts produced higher levels of esters. Although the secondary compounds are desirable for the organoleptic characteristic of the final spirit, they should be within allowable limits. The numerous factors affecting organoleptic property can be used in different combinations. This therefore means that different kinds of agave spirit can be produced at the fermentation stage. This fact is exploited in the beer industry where bottom fermenters, the lager yeasts produces lager beer while the top fermenting yeast produces ale beer. The top fermenters require higher temperature and are more vigorous fermenters while the bottom fermenters require low temperatures and ferments more slowly. The choice of yeast for example, has been suggested to play a critical role in the final organoleptic property even more than the type (species) of agave used (Pinal *et al.,* 1997). To this day however, *S. cerevisiae* remains the most popular yeast employed for fermentation in tequila distilleries. In some cases, albeit traditional, spontaneous fermentation is employed (Amaya-Delgado *et al*., 2013).

Distillation Process

At the tequila distilleries, the fermented mash is then double distilled in pot stills to obtain the agave spirit (Cedeño, 1995). The first distillation is called stripping (Rogelio *et al*., 2005) or breaking (Valenzuela-Zapata, 1985) and results in three products (Rogelio *et al*., 2005). These are;

i) A light product also known as heads, which may be recycled to the fermented mash for re-distillation.

ii) A tail product also known as *vinanza* or vinnases.

iii) A slop cut product called tequila *ordinario* in tequila distilleries, having ethanol content of 20-20% in volume.

The tail product can be discarded. The tequila *ordinario* is then distilled further to tequila *rectificado*. The second distillation is called rectification (Rogelio *et al*., 2005; Valenzuela-Zapata, 1985) and also results in three different products.

i) A second head product which is also discarded.

ii) A second tail product which may be recycled back to stripping.

iii) A distillate - the actual tequila in tequila distillery.

Heating in both distillation steps is achieved by means of low pressure steam passing through a boiler coil located at the bottom of the pot still (Rogelio *et al*., 2005). The separation of the products aforementioned appears not to follow a specific laid down standards. Sometimes it is done by estimating the distillate ethanol content, collection at predetermined time and sometimes following the family old distillation recipes (Rogelio *et al*., 2005).

Heating was initially done in copper pots due to good conductivity. However due to the final high copper content in the spirit produced, some producers use the stainless steel in the stripping stage and copper in the second distillation (Rogelio *et al*., 2005).

Agave spirit produced at this stage can be bottled and sold. At the tequila distillery it is known as tequila *blanco*/silver (Valenzuela-Zapata, 1985).

There is slight modification of the distillation stage in the South African industry. Instead of double distillation, triple distillation is done (Laubster, 2017). Triple distillation has however been found to impact negatively on the quality of agave spirit taking tequila as the standard (Chadwick, 2011).

Ageing/Maturation of Agave Spirit

Maturation is a slow transformation process that enables agave spirit acquire a peculiar flavor, during its residence inside white oak containers (*Quercus alba*) or holm oak containers (*Quercus ilex*) (López-Ramírez *et al*., 2013). Based on maturation period, different types of tequila are obtained at the tequila distillery. In the first two types listed below there is no aging done.

i) *Blanco*/Silver.- this product may be bottled after distillation and alcohol content adjustment (López-Ramírez *et al*., 2013) or remain in the stainless steel tanks for up to 60 days before bottling (Chadwick, 2011). It has the true flavor of the blue agave. Tequila *blanco* is the term used in Mexican tequila industries while this type of agave spirit at a South African distillery is called *Esparanzo.*

ii) *Joven/*gold.-this is a product that is smoothened by adding authorized products.

iii) *Reposando/*Aged-this is a product matured for a minimum of 2 months in oak barrels.

iv) *Aǹenjo/*Extra aged-this is a product matured for at least one year in 600 *l* maximum oak barrels. 350 *l* casks however are more desirable (Chadwick, 2011).

v) *Extra aǹenjo/*ultra-aged-the product is matured at least 3 years in 600 *l* maximum oak barrels.

Other South African brands include *La Leona*, and *Dia noche* which are produced by cooking the agave heads with lava rocks (Laubster, 2017).

There is no kind of agave spirit that owes its origin on the type of oak barrel from which it matured in. Different types of oaks, holm oak or white oak, has nevertheless shown differences in the flavor of agave spirit produced (López-Ramírez *et al*., 2013). Geographical origin of the oak trees have also been shown to influence the flavor of agave spirits (López-Ramírez *et al*., 2013). With Kenya's Meru oak (*Vitex keniensis*), production of agave spirits in Kenya offers a new potential for newer flavors. Similar trees or natural containers like the gourds may also be considered for maturation with a view to create more flavors.

Quality Control

Before tequila is sold it is first subjected to quality control to check for impurities and permitted levels of the secondary products (Valenzuela-Zapata, 1985). The table below shows the permitted range for different chemicals in different brands of tequila. This is by the Mexican standards.

Table 1: Mexican Official Standards for Chemical Specifications for Different Brands of Tequila

Type of tequila	Alcoholic strength (vol.%)	Dry extract (g/l)	Higher alcohols	Methanol	Aldehydes	Esters	Furfural
Blanco ('Silver')	38.0–55.0	0–0.2	20–400	30–300	0–40	3–270	0–1
Oro ('Gold')	38.0–55.0	0–5.0	20–400	30–300	0–40	2–350	0–1
Reposado ('aged') and Añejo ('extra-aged')	38.0–55.0	0–5.0	0–400	30–300	0–40	2–360	0–1

Credit:(Bauer-Christoph *et al*., 2003)

Gas Chromatography has been found to be the most suitable in checking for any breach of the limits (Bauer-Christoph *et al*., 2003).

Other Uses of Agave Plants Apart from Spirit Production

Source of Fructans from Inulin

The presence of inulin in the agave plants could perhaps make it among the most important plants. Inulin is a polydisperse chain of fructose units having degrees of polymerization ranging from 2-60, but normally having an average of 12 (Valenzuela-Zapata, 1985; Boguslavsky *et al*., 2007). It is a generic term that covers all β(2→1) linear fructans (Roberfroid, 2005). Currently the tubers of Jerusalem artichoke (*Helianthus tuberosus*) and the root chicory (*Chicorium intybus* var. *sativum*) are the major commercial sources of fructans (Starbird *et al*., 2007). Commercially, fructan are mainly used as food additives, dietary fiber, and as food for the diabetic's (Starbird *et al*., 2007). Inulin and fructose syrup industries in Mexico was developed to utilize the surplus of agave due to oversupply to tequila distilleries (Coelho, 2007). Listed below are the several uses of inulin and inulin-based products.

I. **It can be used as a prebiotic**. A prebiotic is a substrate that enrich specific beneficial bacterial populations along the gut (Patterson & Burkholder, 2003). In this capacity, it can be ingested and modifies the intestinal normal flora. A healthy colon flora is that which is predominantly saccharolytic, and comprises significant numbers of bifidobacteria and lactobacilli (Cummings *et al*., 2004). Inulin, oligofructose or fructo-oligosaccharide are the best known prebiotics (Cummings *et al*., 2004) and favours proliferation of *Bifidobacterium* in the colon hence promoting health of the host (Roberfroid, 2005). The increase in *Bifidobacterium* results in a concomitant increase in the production of short chain fatty acids which enhance gastrointestinal functions (Meyer & Stasse-Wolthuis, 2009). The proliferation of *Bifidobacterium* has also been shown to have cholesterol lowering activity (Delzenne & Kok, 2001). Further the bacterium inhibits the development of other pathogenic bacterium in the gut (Starbird *et al*., 2007).

II. Inulin type fructans also **enhance absorption of calcium and magnesium** in the gut (Roberfroid, 2005).

III. In the food industry, fructans from inulin can be used as **low calorie sweeteners** (López-Molina *et al*., 2005; Roberfroid, 2005). This is particularly important as the global burden of obesity is projected to go up by 57.8% among the adults by the year 2030 with the trend being more rapid in the developing countries (Kelly *et al*., 2008). Low calorie food will hence increase in demand.

IV. Further, inulin has been found to **reduce the generation time** of bacterial cultures and hence accelerate industrial fermentation processes (Oliveira *et al*., 2011).

V. Long chain inulin has been successfully used as **vaccine adjuvant** due to its ability to stimulate the alternative-complement-pathway (Cooper, 1995).

VI. It has also been used in the **preparation of 'microspheres'** for the controlled release of drugs (Poulain *et al*., 2003).

An agave spirit industry therefore offers great chance of industrial inertia due to diverse agave products. In Mexico, about 38,000 workers are employed in tequila industry alone (Ganduri *et al*., 2015). There is a rapidly growing market for the fructans globally (Ganduri *et al*., 2015). Currently fructans are produced industrially from chicory; a plant belonging to the family *compositae* (Roberfroid, 2005). Inulin from agave plants have been found to be of better quality (Boguslavsky *et al*., 2007). It is by having an agave spirit industry that the use of agave to make inulin based fructans feasible.

Production of Biofuels

Conventional feedstock for bioenergy include sugarcane, maize, sugar beet, wheat, lignocellulosic materials from herbaceous woody crops, oil crops like soybean, rapeseed, jatropha and agricultural residues (Garcia-Moya *et al*., 2011). Unlike most of the common feed stocks, agave is not a basic food crop and grows in areas unsuitable for agriculture, making them excellent candidates for bio-fuel research and development (Valenzuela, 2011). The first generation of bio-ethanol production from blue agave in Jalisco (western Mexico) is beginning to take shape as a byproduct of tequila production and is estimated to have annual production of 110 million litres (Valenzuela, 2011). In the production of biofuels, CAM physiology offer benefits beyond just circumventing the conflict with food and feed production. Some of the benefits are listed below;

I. **Low amounts of lignin in the composition of CAM tissue** (Garcia-Reyes & Rangel-Mendez, 2009). Agave leaves have 3-15% lignin by dry weight and up to 68% cellulose. Lignin is the major impediment to the digestion of lignocellulases to release sugars allowing for fermentation of cellulose and hemicellulose to fuels (Davis *et al*., 2011). Conventional plant feedstock can be up to 30% lignin (Carroll & Somerville, 2009).

II. **Accumulation of soluble non-structural carbohydrates to support PEPC-mediated carboxylation** (Borland *et al*., 2009). The high soluble carbohydrate reserves would require less energy for the conversion to fuels (Smith, 2008).

An established agave spirit industry would provide a model for the biofuel production. It is estimated that with the current trend, demand for bioethanol products is going to double in the next few years (Valenzuela, 2011).

Summary of Uses of the by-Products from Agave Spirit Distilleries

Table 2. Summary of the Possible Uses of By-products of Tequila Production

By-product.	Stage produced.	Potential use(s)	References.
Leaves.	Harvesting and cutting of agave to make heads.	Produce more ethanol. Produce fibers (sisal). Paper making.	(Cedeño, 1995) (Davis *et al.*, 2011) (Boguslavsky *et al.*, 2007)
Bagasse.	After milling and pressing out the juice.	Second generation bio-fuels. Paper making. Mattress stuffing, fodder, organic fertilizer and in brick making,	(Valenzuela, 2011) (Boguslavsky *et al.*, 2007) (Valenzuela-Zapata, 1985)
Vinanza.	Residue after the first distillation	Compost. Fertilizer. Livestock nutrient supplements.	(Iñiguez-Covarrubias *et al.*, 2010) (Boguslavsky *et al.*, 2007; Valenzuela-Zapata, 1985)
Tail.	Waste after the second distillation.	Used as solvent in paints.	(Valenzuela-Zapata, 1985)

The table above shows that agave plants can be 100% useful. This would improve the sustainability of industrial production of agave spirits.

Possible Hindrances to Agave Spirit Production in Kenya

Time

Unlike the common raw materials used in the beverage industry, agave takes an incredibly long time to mature. A typical plant would take at least 8 -12 years to mature. Production of an ultra-aged agave spirit would take at least 4 more years due to additional maturation period. This creates a picture of a risky business venture since even though the market conditions may be promising right now, it may be difficult to predict market behavior after 15 years. Uncertainties are also perpetuated by frequent political instabilities in Africa.

Agave Diseases

Though diseases may not be common in the agave plants, vegetative propagation may change these dynamics. Since this is akin to cloning, agave plantation would be equally vulnerable to diseases. Cultivation of such genetically identical agave plants in large tracts of land, exerts huge selective pressure for the pathogens. Common disease is the agave wildfire caused by *Fusarium oxysporum* that ravaged agave fields in the 90s in Mexico (Valenzuela, 2011). Such diseases can be catastrophic in epidemic levels.

CONCLUSION

As highlighted in this paper, agave cultivation offers great promise to unlocking the economic potential of arid and semiarid lands in Kenya. Production of agave spirit, inulin and fructose syrup industries, and biofuels would help boost industrialization resulting in several direct employment opportunities. Though the most popular name of agave spirit is tequila, such spirits produced in Kenya can’t be referred by that name due to legal implications. With the government providing an enabling environment, this can be a rewarding venture for a potential investor.

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