

Beers from malted gluten-free and climate smart pearl millet or sorghum grains: Their physicochemical properties and principal volatile compounds

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Abstract

Omalovu giilya is an opaque beer from Namibia brewed using malts of pearl millet (*mahangu*) or sorghum. There is limited data on physicochemical properties and volatile compounds of *omalovu*. The study investigated the pH, titratable acidity, alcohol, colour, and principal volatile compounds of *omalovu* brewed using malts of pearl millet varieties (*Okashana 2*, *Kantana*, and *Kangara*) and sorghum (*Macia* and a landrace referred to as Red sorghum) varieties. *Omalovu* was fermented for 9 hours at temperature of 37°C. *Omalovu* pH, alcohol, titratable acidity, and calories were within the reported ranges of other sorghum or pearl millet opaque beers. However, the values of *omalovu* physicochemical properties were generally lower compared to the reference commercial lager beer used. *Omalovu* brewed using the malts of *Okashana 2* pearl millet variety and of *Macia* sorghum variety had significantly higher pH, alcohol, titratable acidity, and calories than all other *omalovu* samples. The compositions of diacetyl, n-propanol, isobutanol, ethyl acetate, amylalcohol, and acetaldehyde in *omalovu* samples were lower or within given range for barley lager beer but were like the values reported for sorghum opaque beer. *Omalovu* brewed using the malts of *Okashana 2* pearl millet variety had a significantly higher 2,3-pentanedione, n-propanol, isobutanol, amylalcohol, and acetaldehyde than other *omalovu* samples. These climate-smart, gluten-free grains can produce beers that with processing optimisation can be of commercial value in the uncertain future battling with climate change effect, and potentially suitable for individuals affected by gluten intolerance and ataxia and celiac issues.

Introduction

Omalovu giilya or *omalodu oilya* in Oshiwambo, *Chikontini in Sifwe* and *Subia* language in Namibia refers to sorghum or pearl millet malt beers. It is brewed using malts of gluten-free pearl millet (*Pennisetum glaucum* (L.) R.Br.) commonly known as *mahangu* or of sorghum (*Sorghum bicolor* (L.) Moench). It is a heterogeneous, opaque, and unpasteurised low alcoholic beer (Embashu et al. 2019). *Omalovu* is traditionally brewed for cultural occasions such as weddings, birth

ceremonies, and thanksgiving (*Oshipe*). Industrial brewing of beers using imported barley malts and other ingredients dominates the Namibian beer market as it does in southern Africa and Africa in general. It is noteworthy that the brewing of sorghum and pearl millet beers hold great significance in the semi-arid and arid regions. This is due to the adaptation of sorghum and pearl millet to growing in dry and hot parts of the earth such as in sub-Saharan Africa. In Africa, some of the countries such as Niger, Nigeria, Mali, Zimbabwe, Ethiopia, Burkina Faso, Cameroon, Mozambique,

Angola, South Africa, Botswana, and Namibia produce pearl millet and sorghum (Cruckshank 2016; Taylor 2016). Consequently, these grains hold promise in a future that is faced with climate change. With the threat of elevated temperatures in the future, these cereals can be potentially climate smart as they are able to grow in prevalent semi-arid conditions (Cruckshank 2016; Taylor 2016) and can thus be used industrially in the brewing of beers. Furthermore, they can reduce the importation into Africa of temperate grains such as barley, and the utilisation of locally grown cereals can be diversified in manufacturing value-added products such as beer.

Characteristics of western beers made from especially malted barley have been reasonably well documented (Briggs et al. 2004; Pavsler & Buiatti 2009; Kucharczyk & Tuszyński 2018; Alves et al. 2020). Regarding African beers, most of which are traditionally brewed, there are significant gaps in knowledge although some characteristics such as pH (3.3–4), alcohol (2–4.5% v/v), colour (from pale puff to pink-brown) (Lyumugabe et al. 2012), lactic acid 0.3–0.6%, and solids 4–10% (Rooney 1996) of opaque beer from sorghum have been reported. One of the key gaps in knowledge is on the volatile constituents' fingerprint and characterisation of *omalovu*. For instance, there is limited information on the aroma and flavour compounds in beers brewed using sorghum malt except as reported by Budner et al. (2021) and Lyumugabe et al. (2013) for *ikigage*. Regarding *omalovu* brewed using pearl millet malt, there is little information (Embashu et al. 2019) on the characteristics of this opaque beer and certainly no literature on its aroma and flavour profile and volatile compounds fingerprinting. Therefore, this brief study investigated some physicochemical properties and principal volatile compounds that most likely contribute to the aroma and flavour of *omalovu* brewed using malts of three varieties of pearl millet and two varieties of sorghum.

Material and methods

Grain collection and preparation

Cereal grains (three varieties of pearl millet, namely *Kangara*, *Kantana*, and *Okashana 2*, and two varieties of sorghum, namely *Macia* (white) and *Red sorghum*) were grown and malted as described in Embashu & Nantanga (2019), except that the germination was carried out at 30°C for two days.

Flow process of brewing *omalovu*

Omalovu was brewed following the flow process outlined by Embashu et al. (2019) as shown in Figure 1 with 0.2% (v/v) *oshikundu* as inoculum.

Physicochemical properties of *omalovu*

The physicochemical properties of *omalovu* from pearl millet and sorghum were determined on fresh and

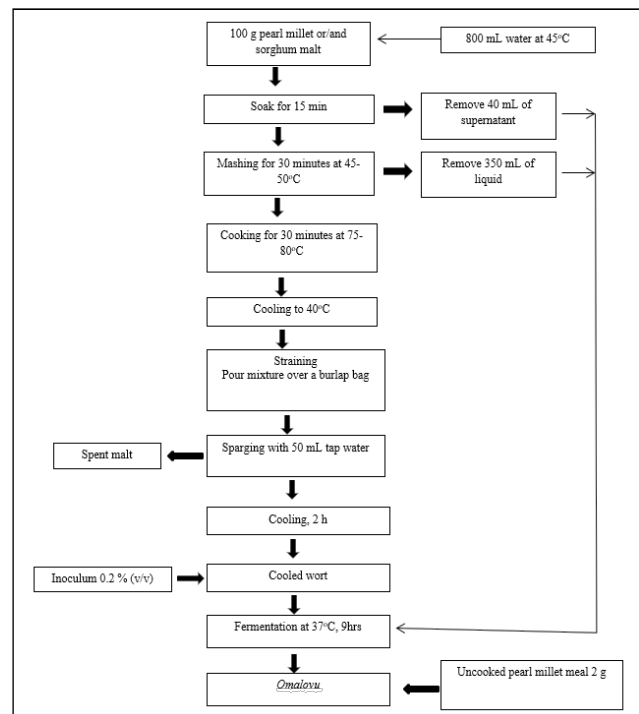


Figure 1: Flow process of brewing *omalovu* using pearl millet or sorghum malt

fermented (9 hours) samples. A commercial malted barley lager beer was used as a positive reference.

Determination of titratable acidity and pH

The pH meter (Eutech, Singapore) was used to measure the pH. Titratable acidity was determined following the method reported by Tyl & Sadler (2017).

Determination of alcohol and calories

Alcohol and calories were determined using alcohol analyser (Anton Paar, DMA 4500) by aliquoting 25 mL of *omalovu*.

Determination of colour

The EBC value of *omalovu* was determined according to the standard Analytica-EBC colour measuring method (European Brewery Conversion, 1975). About 3 mL of *omalovu* was transferred by pipette into a cuvette. Absorbance was measured using a UV-Vis spectrophotometer (Thermo Scientific, USA) at 430 nm.

Determination of congeners

Congeners were determined by centrifuging 300 mL of *omalovu*. Internal standards hexanedione, butanol, and heptanone were added and mixed. Then, 2 mL *omalovu* sample was transferred in headspace (Agilent Technology 7697A, China) vials and fractionation was

carried out on gas chromatography (Agilent Technology 7890B, China) with flame ion detector (FID) and electron capture detector (ECD). The columns used were DB-wax and DB-5 (Agilent Technology, China) with dimensions 60 m x 530 µm x 1 µL, film 1.00 µm (DB-wax) and 1.50 µm (DB-5).

Statistical Analysis

Grains were malted once and brewing was repeated once (twice replicated brewing) for each of the cereal varieties. All analyses were repeated five times ($n = 6$) except the analyses of congeners which were repeated three times ($n = 4$). The effects of malted pearl millet and malted sorghum on *omalovu* physicochemical properties and congeners were determined using one-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) test at $p \leq 0.05$ using R software (version 3.5.2, Austria).

Results and Discussion

Physicochemical properties of *omalovu*

Titrateable acidity, pH, alcohol content, calories, and colour of *omalovu* are given in Table 1. The pH of wort and *omalovu* differed statistically ($p \leq 0.05$). The pH decreased following fermentation up to 9 hours. The pH values of *omalovu* were within the range of 3.06–4.34

reported by Embashu et al (2019) for sorghum opaque beer. Compared to the reference commercial beer, the pH of *omalovu* was lower. Alcohol was detected in *omalovu* irrespective of malt cereal used. Among *omalovu*, the samples made using the malt of *Okashana 2* displayed significantly higher alcohol content ($p \leq 0.05$) than all the others. Furthermore, there was a significant difference ($p \leq 0.05$) in the alcohol content of *omalovu* brewed using the pearl millet varieties. These alcohol content findings were within the range of 0.18–5.0% (v/v) reported by Lyumugabe et al. (2012) and Embashu et al. (2019) for sorghum beer. There was no significant difference ($p > 0.05$) in the titrateable acidity expressed as lactic acid in wort irrespective of the malted cereals used. However, titrateable acidity increased following fermentation. The titrateable acidity was in the following order: malted *Kantana omalovu* = malted *Macia omalovu* > malted *Okashana 2 omalovu* = malted *Kangara omalovu* = malted Red Sorghum *omalovu*. These *omalovu* had lower titrateable acidity than the reported 1.8% (Quin1959; Taylor & Emmambux 2008) for *bjalwa bja leotsa*, a pearl millet opaque beer. Nevertheless, this study's titrateable acidity findings were within the range of 0.3–0.6% reported by Rooney (1996) for sorghum opaque beer. Compared to a commercial lager beer, *omalovu* calories were lower than the range 85–125 kJ/100 mL reported by Briggs et al. (2004) but were within the broader range of 31.1–466.6 kJ/100 mL reported by Hlangwani et al. (2021) for sorghum opaque beer. Malted *Kantana omalovu* had significantly higher ($p \leq 0.05$) EBC values compared to other *omalovu* samples. *Omalovu* had significantly darker ($p \leq 0.05$) colours than their respective worts.

Table 1: The pH, alcohol, titrateable acidity, calories and colour of wort and *omalovu* from pearl millet and sorghum malt varieties.

Sample	pH	Alcohol (% v/v)	Titrateable acidity (%)	Calories (kJ/100 mL)	Colour (EBC units)
Pearl millet wort					
Malted <i>Okashana 2</i>	5.5 ± 0.1 ^b	ND	0.1 ± 0.0 ^c	88.0 ± 8.1 ^a	10.0 ± 1.2 ^h
Malted <i>Kantana</i>	5.9 ± 0.1 ^a	ND	0.1 ± 0.0 ^c	69.9 ± 0.7 ^{cd}	17.4 ± 1.9 ^f
Malted <i>Kangara</i>	5.9 ± 0.0 ^a	ND	0.1 ± 0.0 ^c	76.7 ± 3.4 ^{bcd}	14.6 ± 0.7 ^g
Sorghum wort					
Malted <i>Macia</i>	5.6 ± 0.1 ^b	ND	0.1 ± 0.0 ^c	76.4 ± 0.9 ^{bcd}	27.7 ± 0.7 ^d
Malted Red Sorghum	6.0 ± 0.1 ^a	ND	0.1 ± 0.0 ^c	55.7 ± 13.2 ^e	15.0 ± 3.4 ^g
Pearl millet beer (<i>omalovu</i>)					
Malted <i>Okashana 2</i>	3.9 ± 0.2 ^{cd}	0.5 ± 0.0 ^a	0.3 ± 0.1 ^b	81.7 ± 9.3 ^{ab}	39.6 ± 0.1 ^b
Malted <i>Kantana</i>	3.9 ± 0.01 ^{de}	0.4 ± 0.0 ^b	0.5 ± 0.1 ^a	67.5 ± 0.7 ^d	52.1 ± 0.4 ^a
Malted <i>Kangara</i>	4.0 ± 0.0 ^c	0.3 ± 0.0 ^c	0.3 ± 0.0 ^b	80.6 ± 1.9 ^{ab}	34.2 ± 2.5 ^c
Sorghum beer (<i>omalovu</i>)					
Malted <i>Macia</i>	3.8 ± 0.1 ^e	0.1 ± 0.0 ^d	0.5 ± 0.1 ^a	78.5 ± 1.1 ^{abc}	28.9 ± 0.9 ^d
Malted Red Sorghum	3.9 ± 0.1 ^{de}	0.1 ± 0.0 ^d	0.3 ± 0.1 ^b	56.6 ± 13.6 ^e	19.3 ± 0.8 ^e
Commercial beer	4.2–4.34	4.9			6.80–7.30

Note: values are mean ± standard deviation; values with the same letter in a column are not significantly different ($p > 0.05$); ND, not detected; $n = 6$.

The reference commercial beer had a lighter colour compared to all the *omalovu* samples. Perhaps the difference in colour can be attributed to the microfiltration process applied during the processing of the reference commercial beer, which was not applied during the processing of *omalovu*.

Congeners in *Omalovu*

Congeners of the wort and *omalovu* are given in Table 2. All the congeners found in *omalovu* in this study have been reported in malted barley lager beer (Baxter & Hughes 2001; Briggs et al. 2004) and sorghum beer *ikigage* (Lyumugabe et al. 2013). The diacetyl content statistically differed ($p \leq 0.05$) between wort and *omalovu* except that those of malted *Kantana omalovu* remained statistically unchanged ($p > 0.05$) following fermentation. Malted *Kantana* and *Kangara omalovu* had a significantly higher ($p \leq 0.05$) diacetyl content than all the other *omalovu* samples. Diacetyl is attributed to the butterscotch aroma in beers (Krogerus & Gibson 2013). The diacetyl contents of *omalovu* were within the range of 20–80 $\mu\text{g/L}$ reported by Briggs et al. (2004) for malted barley lager beer. However, the diacetyl content of malted *Macia omalovu* was lower than the same reported range by Briggs et al. (2004) for malted barley lager beer following fermentation. The diacetyl content of *omalovu* was lower than 16.3 $\mu\text{g/L}$ reported by Lyumugabe et al. (2013) for *ikigage*, a sorghum opaque beer. Krogerus & Gibson (2013) attributed a toffee-like flavour to 2,3-pentanedione in malted barley lager beer. In this study, fermentation of wort into *omalovu* significantly ($p \leq 0.05$) decreased the content of 2,3-pentanedione regardless of malted cereal used. The 2,3-pentanedione contents were in the following order: malted *Okashana 2 omalovu* = malted *Kangara omalovu* > malted Red sorghum *omalovu* > malted *Macia omalovu* > malted *Kantana omalovu*. The 2,3-pentanedione contents in this study were higher than those reported by Briggs et al. (2004) for malted barley lager beer, which ranged between 0.01 and 0.5 mg/L. The contents of diacetyl and 2,3-pentanedione in beers can be attributed to the concentration of wort free amino nitrogen and the amino acids as they influence the formation of acetoxy acid that is converted into vicinal diketones (Briggs et al. 2004). Dimethyl sulfide (DMS) was not detected from wort irrespective of malted cereal used. The DMS content of *omalovu* differed significantly ($p \leq 0.05$), except those of malted *Kangara* and malted *Macia omalovu*. Malted Red sorghum *omalovu* had the highest DMS content. The *omalovu* DMS contents were relatively higher than the range of 30–100 $\mu\text{g/L}$ reported by Briggs et al. (2004) for malted barley lager beer and were also higher than 3.2 $\mu\text{g/L}$ reported by Lyumugabe et al. (2013) for *ikigage*, a sorghum beer. DMS content in beers can be influenced by conditions used during malting as they influence the amount of DMS and DMSO formation, conversion of S-methylmethionine (SMM) to DMS during fermentation and temperature during wort boiling and wort stand time (Briggs et al. 2004). The DMS contributes sweetcorn flavour or can smell like cooked cabbage in lager beers, as reported by Briggs et al. (2004). The n-propanol was not detected in any of the worts and in *omalovu* samples produced using malted Red sorghum, malted *Macia*, and malted

Kangara. N-propanol was detected in malted *Okashana 2* and malted *Kantana omalovu* samples. These samples had lower n-propanol contents than the 5–10 mg/L reported by Briggs et al. (2004) as well as the 114.5–212 mg/L reported by Lyumugabe et al. (2013) for malted barley lager and *ikigage* a sorghum beer, respectively. Isobutanol (2-methylpropanol) content significantly ($p \leq 0.05$) increased following fermentation. Malted *Okashana 2 omalovu* had a significantly higher ($p \leq 0.05$) isobutanol content than all the other *omalovu* samples. These study findings were within the reported range of 6–11 mg/L (Briggs et al. 2004) for malted barley lager beer. However, these study findings were lower than 24.8 mg/L isobutanol reported by Lyumugabe et al. (2013) and higher than the isobutanol content of 3.1 mg/L reported by Coulibaly et al. (2021) for similar malted sorghum opaque beers *ikigage* and *tchapalo*, respectively. Amyl alcohol (3-methylbutanol) was not detected in wort samples and in malted *Macia omalovu*. Coulibaly et al. (2021) also reported similar observation where amyl alcohol was not detected in wort of malted sorghum opaque beer *tchapalo*. Amyl alcohol contents of *omalovu* were in this order: *Okashana 2* = *Kantana* > *Kangara* = Red sorghum. The amyl alcohol content of *omalovu* was lower than 32–85.2 mg/L reported by Briggs et al. (2004) for malted barley lager beer and by Lyumugabe et al. (2013) for a similar malted sorghum opaque beer, *ikigage*. These higher alcohols (n-propanol, isobutanol, and amyl alcohol) are common and contribute to the general flowery or solvent-like and alcohol-like aromas in beers. Ethyl acetate was not detected in worts or in malted sorghum varieties *omalovu*, but was detected in malted pearl millet varieties *omalovu* as follows: *Kantana* > *Okashana 2* = *Kangara*. These study findings were lower than 8–14 mg/L reported by Briggs et al. (2004) for malted barley lager beer and 0.7 mg/L reported by Lyumugabe et al. (2014) for similar malted sorghum opaque beer, *ikigage*. The ethyl acetate is generally responsible for fruity aroma or rum-like off-flavours in beers. Acetaldehyde was only detected in malted *Okashana 2 omalovu*. Its content in this study was within the 0–13 mg/L reported by Briggs et al. (2004) for malted barley lager beer and was close to the 0.076 mg/L reported by Lyumugabe et al. (2014) for malted sorghum opaque beer, *ikigage*. Generally, acetaldehyde imparts sourness and unripe apple flavours to beers.

Conclusions

Omalovu pH, alcohol, titratable acidity, and calories were within the reported ranges of other sorghum or pearl millet opaque beers. However, the values of *omalovu* physicochemical properties were generally lower compared to the reference commercial lager beer used. *Omalovu* brewed using the malts of *Okashana 2* pearl millet variety and of *Macia* sorghum variety had significantly higher pH, alcohol, titratable acidity, and calories than all other *omalovu* samples. The compositions of diacetyl, n-propanol, isobutanol, ethyl acetate, amyl alcohol, and acetaldehyde in *omalovu* samples were lower or within given range for barley lager beer but were similar to values reported for sorghum opaque beer. *Omalovu* brewed using the malts of *Okashana 2* pearl millet variety had a significantly higher

Table 2: Congeners of wort and omalovu from pearl millet and sorghum malt varieties.

Samples	Diacetyl (µg/L)	2,3-Pentanedione (mg/L)	DMS (µg/L)	n-Propanol (mg/L)	Isobutanol (mg/L)	Amyl alcohol (mg/L)	Ethyl acetate (mg/L)	Acetaldehyde (mg/L)
Pearl millet wort								
Malted <i>Okashana 2</i>	12.2 ± 0.6 ^f	3.6 ± 0.4 ^f	ND	ND	6.4 ± 0.12 ^{cd}	ND	ND	ND
Malted <i>Kantana</i>	55.5 ± 0.8 ^a	3.5 ± 0.1 ^c	ND	ND	6.3 ± 0.0 ^{cde}	ND	ND	ND
Malted <i>Kangara</i>	43.6 ± 1.5 ^c	4.0 ± 0.1 ^{ab}	ND	ND	6.2 ± 0.0 ^{def}	ND	ND	ND
Sorghum wort								
Malted <i>Macia</i> (white)	47.2 ± 0.8 ^b	4.3 ± 0.1 ^a	ND	ND	6.1 ± 0.5 ^f	ND	ND	ND
Malted Red Sorghum	47.0 ± 0.4 ^b	3.6 ± 0.2 ^{bc}	ND	ND	5.9 ± 0.0 ^g	ND	ND	ND
Pearl millet beer (omalovu)								
Malted <i>Okashana 2</i>	22.0 ± 0.8 ^e	2.7 ± 0.17 ^d	322.2 ± 9.9 ^d	2.3 ± 0.5 ^a	7.1 ± 0.1 ^a	1.2 ± 0.2 ^a	0.08 ± 0.1 ^b	2.3 ± 0.6 ^a
Malted <i>Kantana</i>	56.2 ± 1.8 ^a	ND	430.3 ± 15.8 ^c	0.5 ± 0.8 ^b	6.7 ± 0.2 ^b	1.4 ± 0.3 ^a	0.2 ± 0.1 ^a	ND
Malted <i>Kangara</i>	56.9 ± 0.1 ^a	3.1 ± 0.45 ^d	477.8 ± 6.8 ^b	ND	6.4 ± 0.1 ^c	0.4 ± 0.7 ^b	0.07 ± 0.1 ^b	ND
Sorghum beer (omalovu)								
Malted <i>Macia</i> (white)	8.5 ± 1.8 ^g	1.8 ± 0.0 ^f	454.9 ± 17.7 ^b	ND	6.2 ± 0.1 ^{ef}	ND	ND	ND
Malted Red Sorghum	29.0 ± 1.8 ^d	2.3 ± 0.1 ^e	561.3 ± 21.0 ^a	ND	6.3 ± 0.0 ^{cdef}	0.4 ± 0.6 ^b	ND	ND

Note: values are mean ± standard deviation; values with the same letter in a column are not significantly different ($p > 0.05$); DMS, Dimethyl sulfide; ND, not detected; n = 4.

2,3-pentanedione, n-propanol, isobutanol, amylalcohol, and acetaldehyde than other *omalovu* samples. These climate-smart grains can produce beers that with processing optimisation can be of commercial value in the uncertain future battling with climate change effect.

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About the Author

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Komeine K M Nantanga, who holds a PhD from the University of Guelph, Canada, is an Associate Professor of Food Chemistry and Processing Engineering at the University of Namibia. He is a member of the South African Association for Food Science and Technology, and of the Cereals & Grains Association (formerly the American Association of Cereal Chemists (AACC International)).

His research interests include connecting community diets to their underlying scientific and technological principles to improve the quality of life through intelligent consumption of foods. His key focus on food security is directed at understanding the safety of nutritious foods, especially those that are indigenous, in order to develop shelf-stable varieties for consumers from different socio-economic sectors.



Technical and research services rendered to some of the major food industries and laboratories in SADC, Canada, Croatia, and the USA have provided him with experience in dealing with diverse audiences. He has encouraged the development of learners by sponsoring floating trophies in Mathematics, English, and the Sciences in several education circuits and schools in the Oshana and Oshikoto regions of Namibia.

