Production of malted fermented sorghum-based complementary foods to enhance food and nutrition security in Benue, Nigeria

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Abstract

In Benue, Nigeria, malnutrition continues to be a significant public health concern, affecting mostly infants and young children in the form of impeded growth and development. This study aimed to develop and assess the nutritional quality of malted fermented sorghum-based complementary foods. Soya beans, orange-fleshed sweet potatoes and moringa oleifera leaf powder were sourced locally for the formulations. Individual flours were evaluated for their proximate composition, minerals, vitamins and anti-nutrient content. With the aid of material balancing, four different complementary food samples were formulated to produce 16 g of protein per 100 g sample and they were compared with selected traditional complementary food. The results revealed that treated food samples had improved protein, fibre and mineral content compared to the traditional complementary food. The fat and energy content were highest in the non-malted fermented sorghum-based formulation (4.32 g/100 g and 367.60 kcal/100 g sample, respectively) and the lowest in the traditional complementary food (2.06 g/100 g sample and 358.25 kcal/100 g sample, respectively). Sensory evaluation revealed that, generally, the treated formulations were more acceptable to the panelists. This study demonstrates the potential of malted fermented sorghum-based complementary foods to improve food and nutrition security. From

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the findings, it can be concluded that it is possible to develop scalable and sustainable interventions to treat malnutrition in Benue and Nigeria.

Keywords: sorghum, malting, fermentation, complementary foods, food security, nutrition security, Benue, Nigeria

1. Introduction

Malnutrition is an imbalance in an individual'' intake of nutrients and other dietary elements required for healthy living. It is either the lack of or the excess of food appropriate to an individual's age or physiological state. It has been documented by Zohra et al (2015) that the prevalence of malnutrition has remained consistently high, particularly in low- and middle-income countries (LMICs). This can be attributed to food insecurity in the community and the nation at large. Malnutrition is currently a global challenge of public health importance, although its occurrence is commonly seen in Asia, Africa and South America. As at 2012, according to the Food and Agriculture Organization (FAO), 12.5% of the world's population is malnourished, whereas in 2015 the World Health Organization (WHO) estimated it to be 17.6%. Malnutrition is attributed mainly to developing countries in sub-Saharan Africa, including Nigeria (Who, 2015; Obionu, 2018).

In Nigeria in 2021–22, 37% of children under the age of five were reported to have stunted growth, 21% severely stunted growth, 18% were wasted and 29% were underweight. In Benue, according to the United Nations Children's Fund (UNICEF), 283 727 (21%) children have stunted growth, while 13.6% are reported to be underweight and 54% of child mortality is attributed to malnutrition (UNICEF 2022). Malnutrition therefore remains a public health concern as it affects all ages, but particularly children under five years of age, with impeded growth and development. The prevalence of this condition is said to be accounted for more in children due to their continuous process of growth and development, which necessitates greater nutritional requirements than adults. Other age groups at risk of malnutrition include the elderly, pregnant women, persons experiencing long-term chronic illness such as cancer and those with acquired immune deficiency syndrome (AIDS). The nutrition of young children is highly dependent on mothers because infants are provided with breast milk and older infants are subsequently given complementary and weaning foods to maintain their nutrition.

Local circumstances usually determine the length of time, quantity and quality of food administered by mothers to their children. When a child is not having enough to eat or is not consuming enough of the right nutrients in the correct quantities, they are bound to experience malnutrition. Several factors are known to be associated with malnutrition: key among them are food-security problems related to socio-economic challenges, which are in turn linked to the demand and supply of the required nutrients. Other factors that contribute to malnutrition can generally be categorised as those directly related to the food value chain, such as food production, distribution, preservation and processing. Moreover, other factors such as ignorance, a lack of education, poverty, infection, communal crises and legislation are equally implicated. Inappropriate feeding practices also have a negative impact on children, which increases the chances of ill health with long-term consequences that include poor physical and mental growth and development and compromised productivity. Studies (Onoja et al, 2014; Sadji, 2016; Chadera, 2018) have shown that traditionally prepared complementary foods are bulky or too watery and more often than not are deficient in minerals and vitamins; and their consumption can predispose children to micro-nutrient deficiencies that arise from hidden hunger and its consequences. In addition, according to Onoja et al (2014), it has been documented that the traditional complementary food is more often porridge made from sorghum, maize and millet, which are deficient in the energy and nutrients needed to meet a child's nutritional needs. This brings to the fore the need to formulate complementary food products that would be nutritionally dense derived from locally sourced materials that redress the malnutrition situation in Benue.

The use of readily available raw materials for producing complementary foods has economic benefits to caregivers and also ensures the sustained availability of weaning food throughout the year. This can save caregivers the stress and inconvenience of caring for a malnourished child and can also minimise the cost of purchasing very expensive commercial complementary foods. Patients recovering from chronic illness would also benefit from the product, which is envisaged to have high nutritional value and should be easily digestible, having gone through the treatment process.

Responding to childhood malnutrition requires a multi-sectoral approach in order to achieve comprehensive and sustainable results. The scope of this study therefore focused on food processing and the formulation of malted and fermented sorghum-based complementary food enriched with orange-fleshed sweet potatoes (OFSP), soya beans and moringa for the purpose of providing complementary feeding and weaning. This is expected to promote food and nutrition security, enhance the quality of complementary foodstuffs and improve the production and supply of adequate, balanced, easily accessible and cost-effective food for complementary and weaning purposes.

The aim of the study was to develop, assess and compare the nutritional and sensory effects of traditional and malted or fermented sorghum-based complementary food formulations that are enriched with OFSPs, soya beans and moringa in Benue state.

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2. Literature review

Studies conducted globally have overwhelmingly revealed the benefits of locally formulating complementary food (Onoja et al, 2014). This ranges from the easy accessibility of resource materials and the affordability and general acceptability of the products of such resources. Local circumstances are known to influence the duration or the timing, the quality and the quantity of food administered by caregivers to children. It has been documented that the consumption of a sufficient quality and quantity of complementary food ensures a child's correct mental and physical development. In addition, it improves the immune status of the child and also promotes their recovery from ill health.

Globally, malnutrition remains a major public health challenge, especially in the low- and middle-income countries (LMICs) of the world and it leads to cases of morbidity and mortality (Ofori, 2022). It is a situation in which nutrients in the human body are present in unbalanced quantities, which leads to adverse health conditions. In developing countries, malnutrition in infants and children during the weaning age is equally a public-health challenge and one of the main drivers of morbidity and mortality among children under the age of five (Ezeokeke et al, 2016). Studies have revealed the contribution of malnutrition to high mortality among children under five years of age in developing countries in sub-Saharan Africa. According to UNICEF, 100 children under five years of age are likely to die every hour, and this translates into a daily loss of 2 400 children to malnutrition. In 2023, the proportion of malnourished children worldwide increased from 9.3% to 15.9% (UNICEF, 2023). The prevalent situation has been documented to be associated with the inadequate consumption of protein and/or energy or inappropriate complementary feeding practices (Adepoju et al, 2014; Onoja et al, 2014; Ezeokeke et al, 2016). This has the potential to predispose the at-risk child to high levels of morbidity, impaired intellectual and work performance, and compromised reproductive capacity (Onoja et al, 2014).

Other studies have also revealed that the nutrition of young children is highly dependent on the mother as the child is supplied with breast milk and subsequently older infants are given complementary and weaning food to maintain their nutrition. Malnutrition among infants and young children is currently on the increase as a result of the current hard economic times in addition to a number of other factors, such as climate change, insecurity, poverty, the farmer-herders' crisis and natural disasters such as floods. These factors are known to affect food security severely by creating barriers to the access, affordability, availability and consumption of nutritious foods by infants and young children (Hafiz A, 2016; Tigist et al, 2022; UNICEF, 2023).

Complementary foods are those other than breast milk given to infants for the purpose of providing them with nutrients that aid their growth and development. According to the WHO, the administration of complementary feeding should commence when breast milk alone is no longer sufficient to meet the nutritional needs of infants; for this reason, complementary foods should be given along with breast milk. Adepoju et al (2014) have documented the fact that malnutrition is known to commence during the period of complementary feeding of infants, resulting in morbidity and mortality among children less than five years of age. The WHO has therefore recommended that complementary feeding must be timely and safe. In addition, to improve on its practices, products for complementary feeding must be made locally available, be affordable and easy to prepare and be acceptable to caregivers – in addition to being rich in energy and nutrients (Adepoju, 2014; FMOH, 2023). The intention of the present research was to harness these recommendations for an optimal outcome.

Complementary foods given during this period of 6–23 months of age, particularly in our environment in Benue, are commonly made from cereals (rice, maize, millet), tubers (sweet potato cocoyam) and legumes (soya beans and groundnuts). They are also reported to be poorly blended and therefore of low nutritional value, with high anti-nutritive factors inhibiting the bio-availability of micronutrients (Achibong et al, 2022). In contrast, commercially produced complementary foods are highly nutritious and readily available but expensive, putting them beyond the reach of most rural poor families (Muhimbula et al, 2011; Adepoju et al, 2014; Amal et al, 2014; Pobee et al, 2017).

This research study adopted a methodology that would cover the availability, cost and nutrient quality of the formulated complementary food, in this way bridging the gap.

A complementary food formulated in a Ghanaian study revealed that it was rich in energy and protein; however, it proved to be inadequate in meeting the micro-nutrient demand for vitamin A, iron or zinc (Amagloh et al, 2012). This is similar to the findings of a study carried out in Ethiopia which showed that the complementary food fed to children did not contain sufficient carbohydrate, protein, fat, energy and calcium as recommended, even though the quantity of zinc and iron was adequate (Forsido et al, 2019). Complementary food formulated from fermented sorghum and maize enriched with Cirina forda was documented to have increased levels of macro- and micro-nutrients (Adepoju et al, 2013).

Fermentation is an age-long process known to improve the qualities of foodstuffs such as their appearance, flavour and aroma. It enhances the bio-availability of vitamins, essential amino acids and other micronutrients. In addition, the shelf life is also enhanced

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due to a reduction in the pH of the food (Adeoye, 2024). Malting, in contrast, has been documented to reduce food viscosity, making the child consume more food supplemented in this way. The high level of amylase is known to break down large polysaccharides into glucose and maltose, which improves food digestibility (Forsido, 2020). Therefore, the adoption of a combination of these technologies for cereal processing has the potential to lead to multiple benefits and overcome the challenge of nutrition security.

Studies conducted in Nigeria have revealed that most complementary formulations are made from cereals such as millet, sorghum, maize and rice or tubers such as sweet potato in different proportions (Onoja et al, 2014; Shiriki et al, 2017) The composition of such formulations is a function of access to the available cereal, the knowledge of mothers about food combination and mothers' financial capability. Poor preparation methods such as the over-dilution of products have also been linked to predisposing infants to malnutrition (Ezeokeke, 2016). In Ghana, the Bonsi formulation used OFSP, maize, soya beans, peanuts and fish. An Asma preparation used sweet potato, millet and quinoa. Similarly, Pobell also used OFSP, soya beans, rice and groundnuts for their formulation of complementary foodstuffs. Approval of the use of OFSP, which is a bio-fortified tuber, in the formulation of complementary foodstuffs has been documented by the following studies (Pobee et al, 2017; Ashun et al, 2019). In Nigeria, the Shiriki formulation was produced using maize, soya beans and peanuts fortified with *Moringa oleifera* leaf powder (MOLP) (Shiriki et al, 2017). This is similar to the formulation by Boateng et al (2018) in which the complementary feed was fortified with MOLP. This is because moringa has been known to be nutrient-dense and could therefore be explored as a fortificant in the prevention or treatment of micro-nutrient deficiencies. This is in line with the efficient food approach which recommends the use of indigenous available foods that complement each other, in this way producing formulations that meet an infant's nutrient requirements aimed at reducing malnutrition and micronutrient deficiency in the target population (Chadare et al, 2018).

2. Materials and methodology

Soya beans, OFSP and MOLP were sourced locally for the formulations. The different raw materials were individually processed into flours, as shown in the various flowcharts below. Individual flours were coded and analysed in the chemistry laboratory of the Benue State University using standard methods and procedures by the laboratory technologist. The samples were evaluated for proximate composition, minerals, vitamins and antinutrient content. Using the AOAC method as described by Okoronkwo et al (2023), the moisture content, crude fibre,

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ash, protein and fat were determined whereas the carbohydrate content was determined by difference. The mineral and vitamins content were determined using an atomic absorption spectrophotometer as described by Utoo et al (2022). Tannins and phytate values were assessed using Vanilla-HCL and Wheeler and Ferrel methods respectively. With the aid of material balancing, four different complementary food samples were formulated to produce 16 g of protein per 100 g sample and these were compared with selected traditional complementary foods.

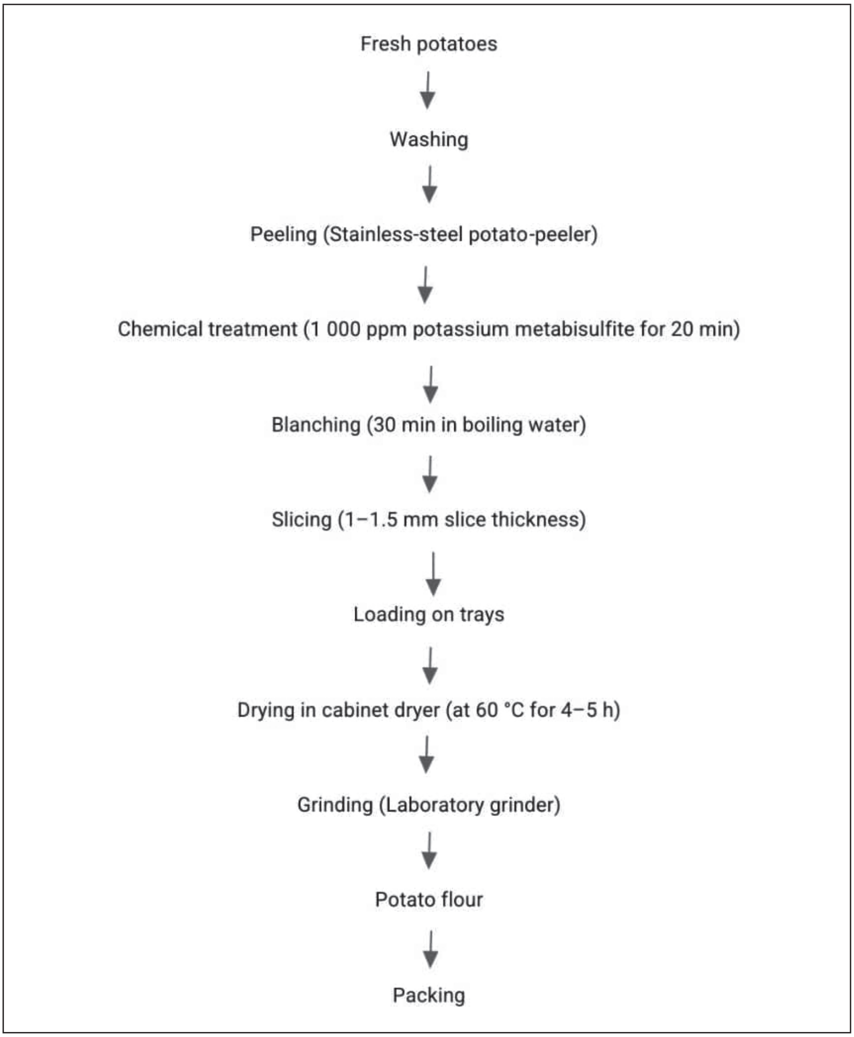

Figure 1: Flowchart for processing of fresh potato flour

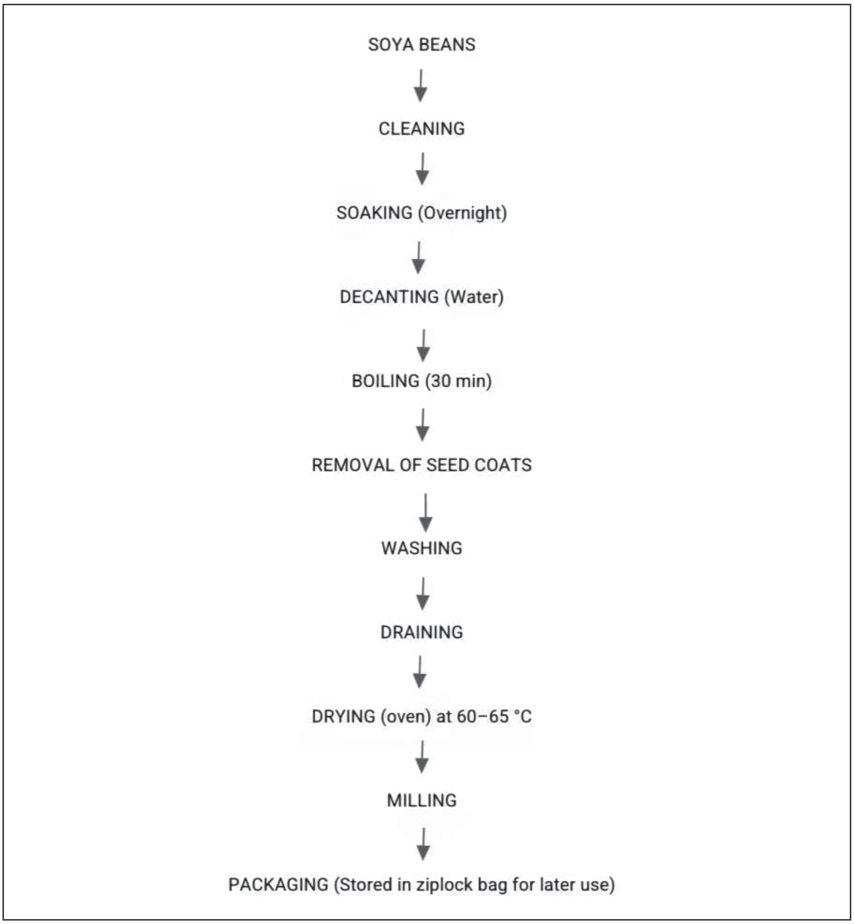

Figure 2: Flowchart for processing soya beans

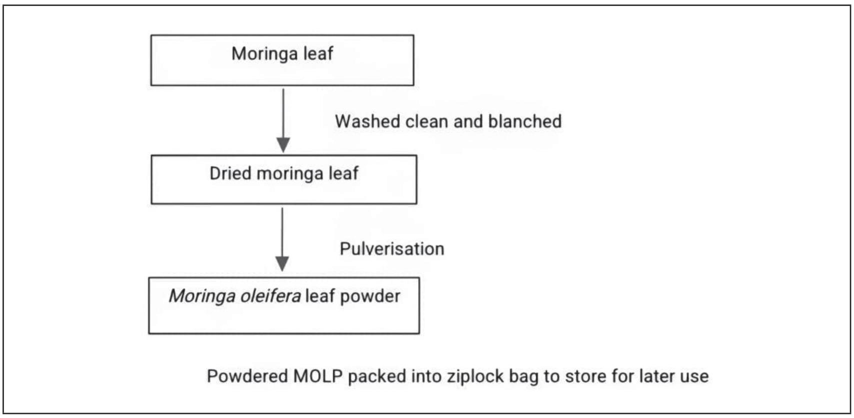

Figure 3: Flowchart for the processing of *Moringa oleifera* leaf powder (MOLP)

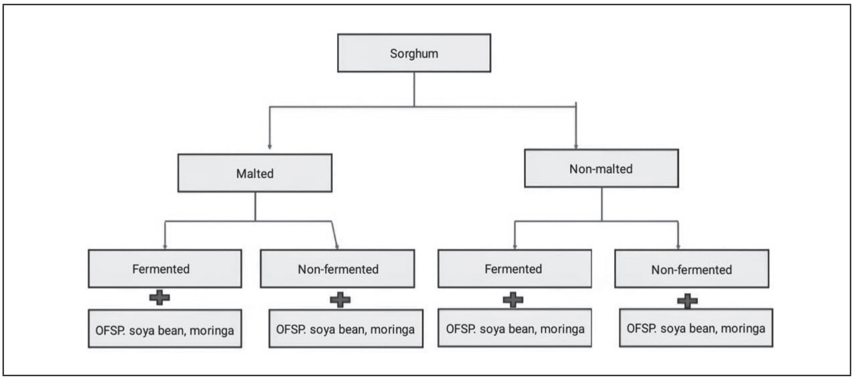

Figure 4: Flowchart for sorghum processing and incorporation with OFSP, MOLP and soya beans

4. Results

This section reveals the findings of the proximate mineral, vitamin and anti-nutrient analysis of the prepared individual flours (sorghum, soya bean, OFSP and MOLP). It equally gives the proximate values of the formulated sorghum-based complementary food in addition to the sensory acceptability values of the prepared gruels as assigned by the panellists made up of health workers and mothers or caregivers.

The proximate analysis of the samples reveals that the individual flours had a different protein content that ranged from 1.68 g/100 g sample to 32.02 mg/100 g sample, with the highest level being recorded in the soya bean whereas the lowest was recorded in the OFSP. Among the treated sorghum samples, the malted fermented sorghum had the highest level of protein, at 7.02 mg/100 g sample. Similarly, the fat content of the samples also varies: the lowest value was observed in the OFSP (0.39 mg/100 g) and the highest value in the soya bean (7.39 mg/100 g). Among the treated samples, the non-malted fermented sorghum had the highest fat value (2.28 mg/100 g), whereas the malted fermented had the lowest value (0.50 mg/100 g). The highest value for ash and fibre was observed in MOLP (7.55 mg/100 g) and (2.57 mg /100 g), whereas their lowest value was recorded in malted fermented sorghum (0.67 mg/100 g) and OFSP (0.02 mg/100 g), respectively. In contrast, OFSP had the highest level of carbohydrates (82.02 mg/100 g), whereas soya bean had the lowest value of 48.74 mg/100 g, as shown in Table 1.

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Table 1: Mean distribution of proximate analysis

Parameter	Sample							
	ECH	NMNF	NMF	MNF	MF	SF	MOLP	OFSP
Protein	8.53	5.54	3.35	6.15	7.02	32.02	10.13	1.68
Fat	2.09	1.14	2.28	1.42	0.50	7.39	0.84	0.39
Ash	1.08	1.84	1.89	1.53	0.67	2.23	7.55	2.96
Fibre	0.05	1.00	0.30	0.09	0.04	1.19	2.57	0.02
Moisture	11.92	11.77	11.58	13.02	11.33	8.43	13.09	12.93
Carbohydrate	76.33	78.71	80.60	77.80	80.44	48.74	65.82	82.02

Key: ECH – External control sample; NMNF – Non-malted non-fermented sorghum; NMF – Non-malted fermented; MNF – Malted non-fermented; MF – Malted fermented; SF – Soya bean flour; MOLP – *Moringa oleifera* leaf powder; OFSP – Orange-fleshed sweet potato

Using material balancing, the individual flours were used to produce four sorghum-based complementary flour blends that would yield a 16 g protein/100 g sample made up of sorghum flour, soya-bean flour, OFSP flour and MOLP.

The proximate analysis of the formulated sorghum-based complementary food samples revealed the highest level of *fat content* in the non-malted fermented sorghum-based sample (4.32 mg/100 g), whereas the external control sample which is the traditional complementary food had the lowest value of fat (2.09 mg/100 g). The non-malted non-fermented sorghum-based sample had the highest *fibre content* (1.11 mg/100 g) and the lowest value in the external control sample (0.05 mg/100 g). The external control sample, however, had the highest *carbohydrate content* (76.33 mg/100 g) with lowest energy level (358.25 kcal/100 g), whereas the non-malted fermented sorghum-based sample had highest energy level 367.60 kcal/100 g), as shown in Table 2.

Table 2: Proximate composition of formulated sorghum-based complementary food

Parameter	Sample				
	ECH	NMNF	NMF	MNF	MF
Protein (%)	8.53	16	16	16	16
Fat (%)	2.09	3.55	4.32	3.57	2.99
Ash (%)	1.08	2.34	2.37	2.17	1.70
Fibre (%)	0.05	1.11	0.78	0.62	0.58
Moisture (%)	11.92	10.57	10.35	11.27	10.44
Carbohydrate (%)	76.33	66.48	66.18	66.05	68.25
Energy (kcal/100 g)	358.25	361.87	367.60	360.88	07

Key: ECH – External control sample; NMNF – Non-malted non-fermented sorghum-based; NMF – Non-malted fermented sorghum-based; MNF – Malted non-fermented sorghum-based; MF – Malted fermented sorghum-based

Analysis of the individual samples also revealed variations in their *mineral composition*: MOLP had the highest level of potassium (1,967.31 mg/100 g) and sodium (62.65 mg/100 g), whereas the lowest values are observed in the malted fermented sample at 96.41 and 6.97 respectively. The soya bean sample had the highest value for calcium (65.27 mg/100 g), whereas the lowest value of 0.05 mg/100 g was recorded in the external control sample as shown in Table 3.

Table 3: Mineral analysis of samples

Parameter	Sample							
	ECH	NMNF	NMF	MNF	MF	SF	MOLP	OFSP
Potassium (K)	110.02	1 205.57	894.76	481.25	96.41	292.74	1 967.31	1 254.10
Copper (Cu)	1.83	0.1495	0.1370	0.0711	0.0764	0.3211	0.1157	0.1262
Magnesium (Mg)	35.1294	130.4400	136.9547	114.1822	25.9775	124.3958	152’7961	71.6818
Calcium (Ca)	0.0570	4.2020	7.0000	4.4920	6.8670	65.2700	15.0000	21.5200
Iron (Fe)	0.2440	3.9380	3.9870	3.6810	0.8530	3.3710	6.2700	1.5420
Sodium (Na)	11.9214	7.0429	9.6957	10.4920	6.9663	12.3067	62.6521	13.6478

Key: ECH – External control sample; NMNF – Non-malted non-fermented sorghum; NMF – Non-malted fermented; MNF – Malted non-fermented; MF – Malted fermented; SF – Soya bean flour; MOLP – *Moringa oleifera* leaf powder; OFSP – Orange-fleshed sweet potato

The *vitamin composition* also varied significantly among the samples. Vitamin A was prominently highest in the OFSP with a value of 9.42 mg/100 g and lowest value recorded in the malted fermented sorghum sample 1.90 mg/100 g. In contrast, MOLP had the highest levels of (6.46, 60.90, 7.24, 22.05, 220.51) mg/100 g recorded for vitamins B1, B2, B3, B6 and vitamin C while their lowest values were observed in the non-malted non-fermented sorghum sample (0.74 mg/100 g), soya bean (1.98 mg/100 g) and OFSP (5.67 and 56.68 mg/100 g) respectively, as shown in Table 4.

Table 4: Vitamin analysis of samples

Parameter	Sample							
(mg/100g)	ECH	NMNF	NMF	MNF	MF	SF	MOLP	OFSP
Vitamin A	4.48	4.97	6.55	3.46	1.90	5.37	6.32	9.42
Vitamin B1	1.78	0.74	1.73	1.82	2.62	3.17	6.46	0.89
Vitamin B2	12.89	10.6	20.21	37.97	17.95	1.98	60.90	17.96
Vitamin B3	5.06	3.19	2.80	2.90	2.44	3.66	7.24	2.37
Vitamin B6	11.95	12.10	10.40	10.95	11.76	16.58	22.05	5.67
Vitamin C	119.45	120.99	104.05	109.51	117.55	165.81	220.51	56.68

Key: ECH – External control sample; NMNF – Non-malted non-fermented sorghum; NMF – non-malted fermented; MNF – malted non-fermented; MF – Malted fermented; SF – Soya bean flour; MOLP – *Moringa oleifera* leaf powder; OFSP – Orange-fleshed sweet potato

Similarly, the *anti-nutrient factors* were analysed and observed to differ between the samples: MOLP had the highest levels of oxalete (0.42 mg/100 g), tannin (2.00 mg/100 g) and phytate 0.313 mg/100 g), whereas their lowest values were seen in OFSP and non-malted non-fermented samples (0.08 mg/100 g), non-malted fermented (1.5 mg/100 g) and OFSP (0.029 mg/100 g) respectively, as shown in Table 5.

Table 5: Anti-nutrient analysis of samples

Parameter	Sample							
	ECH	NMNF	NMF	MNF	MF	SF	MOLP	OFSP
Oxalate	0.12	0.08	0.10	0.13	0.15	0.09	0.42	0.08
Tannin	1.78	1.73	1.50	1.76	1.62	1.71	2.00	1.77
Phytate	0.041	0.052	0.058	0.081	0.093	0.064	0.313	0.029

Key: ECH – External control sample; NMNF – non-malted non-fermented sorghum; NMF – Non-malted fermented; MNF – Malted non-fermented; MF – Malted fermented; SF – Soya bean flour; MOLP – *Moringa oleifera* leaf powder; OFSP – Orange-fleshed sweet potato

The *comparative sensory evaluation* of the gruel made from formulated flour blends revealed that *colour-wise* the malted fermented sorghum-based sample was most appealing to both the mother or caregiver and the healthcare workers whereas the least appealing sample for both was the external control sample. The non-malted non-fermented sample was the least appealing, with a mean score of 3.0, whereas most appealing in *aroma* was the malted fermented sample for both mother or caregiver and the healthcare workers, with a mean score of 4.2. The sample with the least appealing *texture* was the external control sample whereas the non-malted non-fermented and the non-malted fermented were most appealing to the mothers or caregivers but the malted fermented was most appealing to the healthcare workers. Regarding *taste*, the non-malted fermented was the least appealing to the mothers or caregivers whereas the malted fermented was most appealing to them. In contrast, the non-malted non-fermented was the least appealing to the healthcare workers, who mostly appreciated the non-malted fermented sample. In general, the non-malted fermented sample was mostly accepted by the mothers or caregivers, whereas the healthcare workers mostly accepted the malted non-fermented and malted fermented sorghum-based samples, as shown in Table 6.

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Table 6: Comparative analysis of sensory evaluation of formulated samples

Parameter	Respondents	ECH	NMNF	NMF	MNF	MF
Colour	Mothers/caregivers	3.4	4.0	4.2	3.6	4.6
	Healthcare workers	3.4	3.4	4.2	4.2	4.4
Aroma	Mothers/caregivers	4.2	3.0	3.8	3.4	4.2
	Healthcare workers	3.6	3.8	3.8	4.2	4.2
Texture	Mothers/caregivers	3.8	4.6	4.6	4.0	4.0
	Healthcare workers	3.6	4.2	4.0	4.2	4.4
Taste	Mothers/caregivers	4.2	4.2	4.0	5.0	5.0
	Healthcare workers	4.0	3.6	4.0	3.8	4.0
General acceptability	Mothers/caregivers	4.4	3.4	4.8	4.5	3.8
	Healthcare workers	3.8	4.0	4.0	4.2	4.2
	Grand mean:	(3.84)	(3.82)	(4.14)	(4.11)	(4.28)

5. Discussion of findings

The proximate mineral, vitamin and anti-nutritional qualities of the processed individual flours were assessed, as was the selected traditional complementary food. The moisture content of the samples varied between 8.43% and 13.0%, although the variation is not far from the acceptable limit of 10%. A higher moisture content could be due to the processing method used, such as fermentation and malting. A lower moisture content is ideally advocated to enhance the product's shelf life. It is also convenient for packaging and transporting the product (Bekele, 2016).

The protein value of the individual flours revealed that the protein content was the lowest (1.68 g) in OFSP and the highest (32.02 g) in soya bean flour; among the sorghum flours, the malted fermented sorghum flour had the highest protein content of 7.02 g. Similarly, OFSP had the lowest fat content (0.39 g), whereas the soya-bean flour had the highest fat content of 7.39 g. In contrast, the OFSP flour had the highest carbohydrate content of 82.02%. The ash content was recorded as highest in MOLP (7.55 g) and lowest in the malted fermented sorghum flour. The mineral content also varies between the individual flours: MOLP has the highest level of almost all the mineral content, except for copper. Similarly, the highest vitamin B1, B2, B3, B6 and vitamin C content was also recorded in the MOLP, whereas OFSP prominently had the highest amount of vitamin A compared to the other individual flours. The anti-nutrient factors were observed to vary between the samples; however, MOLP had the highest levels of oxalate (0.42 mg/100 g), tannin (2.00 mg/100 g) and phytate 0.313 mg/100 g). The variation in the macro- and micronutrients in the individual flours reveals a balanced and nutritious composition when combined for blend formulation. This would fill the gap observed in previous formulations that were deficient in micronutrients (Amagloh et al, 2012; Forsido et al, 2019); the outcome will be a reduction in malnutrition and micro-nutrient deficiency (Chadera et al, 2018).

The formulated complementary foods were similar to those of previous studies (Pobell et al, 2017; Shiriki et al, 2017; Boaten et al, 2018) with modifications. All four formulated blends had a protein content of 16 g per 100 g sample, which was almost double the content of the external control (ie, traditional complementary food), 8.52 g/100 g meeting the WHO recommendation. The external control sample was seen to have the highest moisture and carbohydrate content of 11.92% and 76.33%, respectively, whereas the non-malted fermented sorghum-based complementary food was observed to record the lowest moisture content – 10.35% – but the highest fat, ash and energy content of 4.32%, 2.37% and 367.60 kilocalories, respectively. The lower the moisture content as recommended, the greater the level of stability and the enhanced shelf life of the product (Bekele et al, 2016).

The gruel from non-malted fermented sorghum-based complementary food was also generally most appealing and acceptable to both panelists – with a score of 4.54 – whereas the least appealing gruel was that of the traditional complementary food – with a score of 4.14. The the end users of the formulated complementary foods are infants and children less than five years of age, so they cannot be expected to evaluate the sensory attributes of the gruel. Therefore, we depended on feedback from mothers and caregivers as their general acceptability could possibly translate into product use.

The challenge of malnutrition in Benue State, Nigeria, which is quite prevalent, especially among infants and young children, makes finding innovative and sustainable solutions a dire need. The insights revealed in this study demonstrate the potential to improve the nutritional outcomes of malted and fermented sorghum-based complementary foods which are enriched with soya beans, OFSP and MOLP.

5.1 Redressing hidden hunger through micronutrient fortification

One of the most critical yet often overlooked aspects of malnutrition is hidden hunger – that is, micronutrient deficiencies that disrupt physiological and cognitive development. The locally sourced complementary foods in Benue, which are composed of sorghum or maize porridges, lack sufficient iron, zinc and vitamin A, which can contribute to high rates of anaemia and stunting (FMOH, 2023). As demonstrated in the present study, including MOLP in the formulated foods significantly enhances the iron (6.27 mg/100 g) and calcium (15.00 mg/100 g) content, showing the potential for reversing the deficiencies prevalent in the region.

This particular result agrees with global strategies for promoting dietary diversification and biofortification (Ofori, 2022). For instance, OFSP, which is rich in beta-carotene (a precursor of vitamin A), contributed 9.42 mg/100 g of vitamin A, exceeding locally sourced alternatives. Given that vitamin A deficiency affects 33% of Nigerian children (FMOH, 2023), integrating OFSP into complementary foods could reduce the morbidity linked to immune dysfunction and vision impairment. These results would contribute greatly to achieving goals 2, 3 and 4 of the Sustainable Development Goals (SDGs) that focus on zero hunger, good health and wellness, and also quality education.

5.2 Economic and agricultural sustainability

One of the notable strengths of this study is its emphasised reliance on ingredients that are not only available locally but are also affordable, ensuring its scalability. Sorghum, soya beans and OFSP are drought-resistant crops that are well suited to Benue's agro-ecological conditions. They can be grown even in relatively dry conditions. In promoting these crops for use in the production of complementary foods, the study supports local agricultural value chains and reduces dependence on imported foods. This means that farmers can diversify their income sources by supplying raw materials for food processing. And given that Nigeria spends heavily on importing fortified cereals, locally formulated foods could reduce this economic burden too (Achibong et al, 2022).

In addition, adopting the malting and fermentation processes requires minimal expenditure and relatively basic technological know-how, which means that the common caregiver can key into them even at the household level. Unlike the commercially fortified foods which require industrial processing, these methods empower caregivers in rural communities to improve nutrition without depending on any external intervention (Forsido, 2019).

5.3 Behavioural and cultural considerations in adoption

Despite the fact that formulated complementary foods have demonstrable superiority over traditional feeding practices, cultural acceptability remains a barrier to their acceptance. The local caregivers who are more culturally inclined to their traditional methods still prefer bulky, watery porridges. To them, the resultant weight from the water content found in local food is more nutritionally dense; the reality, however, is that these foods are nutrient-poor, therefore predisposing their consumers to malnutrition.

The mean acceptability score of 4.28, which the sensory evaluation scored in this study, suggests that the new formulations are palatable. However, their long-term adoption requires a consideration of factors such as community education and gender-inclusive training. By means of community training programmes, health workers would be able to demonstrate the link between nutrient density and child growth so that the local people, who crucially comprise caregivers, can be made aware of these matters and make better dietary choices as a result. Gender-inclusive training is crucial, considering the fact that women primarily prepare complementary foods; interventions should therefore target improving on maternal knowledge (Boaten, 2018).

6. Conclusion

The results obtained in this study have shown that the fermented and malted sorghum-based complementary foods have reduced crude fibre, crude fat and total carbohydrate, and phytate and tannin. In contrast, the crude protein and caloric content were more enhanced in the treated samples compared to the traditional complementary food. The prepared gruel from the malted or fermented sorghum-based complementary food was generally most appealing and acceptable to both panellists when compared to the external control, that is, the traditional complementary food. The malted fermented product was the least viscous, translating to more consumption by infants with optimal nutrient gain and caloric intake.

This study has demonstrated the potential of malted fermented sorghum-based complementary foods to improve food and nutrition security. From the findings, scalable and sustainable interventions to deal with malnutrition, and in so doing contributing to achieving goals 2, 3 and 4 of the SDGs in Benue and Nigeria, can be developed.

7. Study strengths and limitations

This study used locally sourced and available raw materials for the complementary food formulation, which, first, can easily be adopted by caregivers and, second, renders the possibility of scale-up easy. The treatment method adopted in this study is quite simple and can be adopted with ease in complementary food in communities. And although this is a promising study, there were gaps in it that warrant further investigation. For instance, this study could not explore microbial studies nor could it carry out shelf-life studies. Subsequent studies should focus on exploring these areas.

Shelf-life stability was an issue, owing to the fact that fermented foods are more prone to spoilage than traditional complementary foods; research is therefore needed on preservation techniques (Adeoye, 2018). There is also the unsubstantiated concern about the impact these fermented foods could have on child growth. Therefore, longitudinal studies should check whether these foods reduce stunting and wasting rates. A cost–benefit analysis should be carried out in which we compare the economic feasibility of household-level production versus centralised manufacturing.

8. Recommendation or policy implementation

To translate these findings into action, measures such as incorporating malted and/or fermented sorghum blends into Nigeria's Infant and Young Child Feeding (IYCF) policies (FMOH, 202) would be beneficial. There should be collaboration with agro-processors to produce pre-packaged blends for both urban and peri-urban markets, and these formulations should be incorporated into school feeding schemes to redress childhood malnutrition holistically (Danwood, 2009).

Moreover, health institutions should build the capacity of health workers who, regularly, could be educating and demonstrating to caregivers the formulation of complementary foods with high nutrients and caloric content.

Higher education institutions should inculcate food formulations, analysis and demonstration in their curricula to enhance hands-on experience and ease of step-down to caregivers when they eventually become doctors consulting at the clinics.

9. Suggestion for further research

Microbial, safety and shelf-life studies which aim at enhancing the durability of final products are recommended for further studies.

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A manuscript will be considered for publication:

1. only on the assurance that it has not in whole or in part or in substance been published or offered for publication elsewhere;
2. on the understanding that it may be submitted in confidence to an expert referee or expert referees for evaluation;
3. on the understanding that the editors reserve the right to make whatever changes they consider desirable:
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   (d) to introduce or enhance accuracy and coherence;
   (e) to improve the mode of expression and style of writing;
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The *IJAR* does not under any circumstances accept work that is broken up into a series of fragmented pieces (part 1, part 2, etc). Each article must stand on its own as a full analysis of the topic under consideration.

Although the *IJAR* recognises the principles referred to in Annexure A below, the *IJAR* will not consider re-publishing a text already published elsewhere. The reputation of the *IJAR* is predicated upon its being the first to publish *original* material.

Authors are required to read their manuscripts very carefully to avoid the need for the editors to exercise these rights extensively. In particular, authors are asked to acquaint themselves with the house style of the *IJAR* and to review either hard copies or PDFs of their work to ensure that they are of publishable quality before submission.

When edited articles are returned to authors for queries to be answered or missing information to be supplied, this should be responded to as quickly and as fully or accurately as possible.

Title, heading and subheading hierarchy

Title

The title should be in bold typeface and centred in the text width; sentence case is preferred:

Cost of reskilling employees versus profitability of a business: a reflection of selected small businesses in Mthatha, Eastern Cape

Author details

Authors should preferably provide their name, affiliation, title, email address and ORCID reference in an unnumbered footnote, as follows:

Dxxxxxxx Gxxxxxxxxxx*

Abstract

Ensure that every main section of your article is covered by at least one sentence in the abstract. To enhance search-engine optimisation (SOE), include keywords in your abstract.

Keywords

A list of keywords must be provided and placed below the abstract; it should be left aligned, with commas separating the keywords. The keywords should be as specific as possible to your research topic.

Keywords: reskilling workforce, Fourth Industrial Revolution, 4IR, automation, profitability, small businesses

* Hamad Bin Khalifa University. Email: dgiustini@hbku.edu.qa ORCID: https://orcid.org/0000-0002-8967-193X

Heading and subheading levels: format

Headings and subheadings should be limited as far as possible to three levels, each formatted and numbered as indicated below:

Level 1: **1. Introduction**

Level 2: **2.1 Cost of reskilling**

Level 3: *2.2.1 Creativity*

Citing references in footnotes

Note in particular the preferred style for referencing various sources: books, journal articles, newspaper articles, online references, case citations, and the titles of treaties, conventions and legislation.

Books

The name of the author of a book or article cited should, on the first occasion it is mentioned in a footnote or an endnote, be given in full exactly as the author gives it (first name or initials). The title of a book is to be in italics, with, if appropriate, the volume number referred to by an uppercase roman numeral (not in italics), the edition (not in italics), year of publication, section or paragraph number and page number (the page number should be preceded by a 'p' only if there is a section or paragraph number). Thus:

Frits Kalshoven & Liesbeth Zegveld *Constraints on the waging of war* 3 ed (ICRC 2001) 53.

James Crawford *The international law commission's articles on state responsibility* (2002) para 4 p 153.

DP O'Connell *International law vol II* 2 ed (1970) 842 (cited in J Dugard *International law: A South African perspective* 3 ed (2005) 238).

Thomas M Franck *Recourse to force* (2002) 49–52.

Roger Crisp (ed) 'The history of utilitarianism' in *Stanford encyclopaedia of philosophy* rev ed (Stanford University 2014) 1.

Sir Hersch Lauterpacht (ed) *L Oppenheim's international law: A treatise vol II: Disputes, war and neutrality* 7 ed (1952) 209.

Jean-Marie Henckaerts & Louise Doswald-Beck *Customary international humanitarian law vol I: Rules* (2005) 291.

Carl von Clausewitz *On war* (English translation by JJ Graham) (1968) 103.

Journal articles

The name of the author of an article cited should, on the first occasion it is mentioned, be given in full exactly as the author gives it (either first name or initials). The title of the article should be enclosed in single quotation marks and follow sentence case (after a colon, the first word of a subtitle should start with a capital letter). Then the year of publication, the volume number and the part number (not in italics), followed by the title of the journal (in italics); the number of the first page of the article or the page range of the article; the specific section or paragraph number and page number (the page number should be preceded by a p if there is a section or paragraph number). Therefore:

Jabbari, J, Zheng, H, Roll, S, Auguste, D & Heller, O 'How did reskilling during the COVID-19 pandemic relate to entrepreneurship and to optimism? Barriers, opportunities, and implications for equity' 2023 *Journal of Family and Economic Issues* 1–20.

Hennie Strydom '*Jus ad bellum* and *jus in bello* in the South African Constitution' (2004) 29 *South African Yearbook of International Law* 78–93 at 82.

Jutta Brunné & J Stephan Toope 'The use of force: International law after Iraq' (2004) 53(4) *International and Comparative Law Quarterly* 785.

Newspaper articles

If mentioned, the name of the author of an article cited should, on the first occasion it is mentioned, be given in full exactly as the author gives it (either first name or initials). The title of the article should be enclosed in single quotation marks. After this: the title of the newspaper (in italics); then; between parentheses, the place of publication and the date of publication; the page number. If the author is not identified, start with the title of the article. Thus:

Duncan Campbell 'Depression and suicide attempts are reported from Guantanamo Bay' *The Guardian* (London, 5 July 2003) 4.

'The Legal Black Hole' *Daily Telegraph* (London, 12 June 2006) 3.

Online references

If mentioned, the name of the author of an article cited should, on the first occasion it is mentioned, be given in full exactly as the author gives it; alternatively, the name of the organisation responsible for the article should be given if there is no author. The title of the article or report should be in sentence case and enclosed in single quotation marks. After that follow the words 'available at', followed by the internet address; then, between parentheses, the date on which the site was accessed: '(accessed 2 May 2023)'. For example:

I Asimov 'Runaround' (1942) www.britannica.com/topic/Runaround

J Engelberger & G Devol 'Unimate' (1954) https://robotnik.eu

IMDb 'Cyborg movies' (25 October 2018) www.imdb.com/list

SY Lee & AJ Hong Psychometric investigation of the cultural intelligence scale using the Rasch measurement model in South Korea' (2021) https://www.mdpi.com/2071-1050/13/6/3139

United Nations 'Report of the Secretary-General to the Security Council' (A/65/820-S/2011/250), available at http://unispal.un.org/UNISPAL.NSF/0/70BF34991DA5D6B08525788E004BA583 (accessed 27 May 2012).

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General Assembly Resolution 1386 (XIV) (adopted on 20 November 1959), available at <http://www.unicef.org/lac/spbarbados/Legal/global/General/declaration_child1959.pdf> (accessed 21 February 2012).

Case citations

As a general rule, the first reference to a case in the body of the text might employ a common abbreviated refence. Thus:

The International Court of Justice (ICJ) defined '*erga omnes* obligations' as follows in the *Barcelona Traction* case: …

However, the footnote reference should provide the full citation: the name of the court handing down the decision; the case name (in italics); between parentheses, the date of the judgment; the case reference – if in a published collection, the title of the collection should be in italics; the number of the first page of the judgment; the specific section or paragraph number and page number (the page number should be preceded by a 'p' if there is a section or paragraph number). Thus:

Abrams v Boyce 2002 (4) SA 305 (EC)

ICJ *Barcelona Traction, Light and Power Company, Limited* (*Belgium v Spain*) (judgment of 5 February 1970) *ICJ Reports* (1970) 3 paras 33–34 p32 (hereafter *Barcelona Traction* case).

ICJ *Legality of the Threat or Use of Nuclear Weapons* (Advisory Opinion of 8 July 1996) *ICJ Reports* (1996) 226, 256 (hereafter *Nuclear Weapons* Advisory Opinion).

SCSL *The Prosecutor v Alex Tamba Brima, Brima Bazzy Kamara and Santigie Borbor Kanu* (Trial Chamber II Sentencing Judgment) (19 July 2007) 36, available at <http://www.sc-sl.orgldocuments/SCSL-04-16-T-624.pdf> (accessed 27 May 2012).

ICTY (Appeals Chamber) *Prosecutor v Radoslav Branin* (3 April 2007) Case No IT-99-36-A para 482.

Treaties, conventions and legislation

The titles of international treaties, conventions and domestic legislation should be in regular script, not italics. When first referred to, the relevant instrument should not be abbreviated; however, if referred to subsequently, an abbreviation might be used – in which case, the first reference to the instrument should be followed by the abbreviation between parentheses.

Thus:

The recruitment of child soldiers was first addressed in the Additional Protocols (API and APII) to the four Geneva Conventions (GC).

A footnote reference should spell out the full name of the relevant instrument, its date and where it might be found. Thus:

> The Geneva Conventions of 12 August 1949, available at <http://www.icrc.org/eng/assets/files/publications/icrc-002-0173.pdf> (accessed 28 May 2013).

In the body of the text, reference to an article should always appear as 'Article'. Thus:

> Article I of the Genocide Convention places the obligation on states 'to prevent and to punish' genocide, and Article IX provides that disputes relating to inter alia 'the responsibility of a state for genocide or for any of the other acts enumerated in Article III' is to be submitted to the ICJ for adjudication.

> The guidance provided in Common Article 3 (CA3) of the GCs as to what constitutes a Non-International Armed Conflict (NIAC) is limited.

In the case of footnotes, 'Article' should be spelt out in full if the first word of the sentence; if not, 'art' (plural 'arts') should be used. In both the body of the text and in the footnotes,

> 'section', with reference to an enactment, is spelt out in full as the first word of a sentence, but otherwise is 's' (plural 'ss'); subsection is 'sub-s' (plural 'sub-ss').

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> 'section' with reference to a book or certain foreign codes of law is § (plural §§).

Cross-referencing

Some hints:

See note 21.

Franck op cit (note 21) at 367.

Franck (note 21) 367.

Franck (n 21) 367.

In the work cited in note 21.

See also s 7.

See text to note 21.

Ibid (meaning in the same place, to be used only immediately below the reference being referred to).

Ibid at 367 (meaning in the place referred to in the immediately preceding footnote, but at page 367, which is different from that in the note above).

Intext referencing

Follow the Harvard style of intext referencing. For instance:

Single author and date: (Aspers, 2019)

Single author, date and page number: (Aspers, 2019: 35–40)

Joint authors within a sentence followed by date: Bahri and Min (2023)

Joint authors in parentheses and date: (Bahri & Min, 2023: 71)

Series of authors and dates in parentheses: (Bahri & Min, 2013; Aspers, 2019) – follow chronological order by date of publication, references separated by semicolons; date order for publications by the same author, dates separated by commas: (Bahri & Min, 2013, 2019; Aspers, 2014, 2019).

Reference list

Your references must also be provided in a reference list at the end of an article and be arranged in alphabetical order according to author surnames (eg Asmal, Z, Carolus, BR) or the names of organisations or institutions (eg World Economic Forum).

Do not separate your published references into different groups or categories (eg books, journals, online sources); treat them instead as one consolidated list.

Ensure that every source cited intext or in footnotes is included in the reference list, and vice versa. Ensure that the details of each reference are both complete and accurate, and are consistent with those provided either intext or in footnotes.

They should be in the same font and line spacing as the body text.

The second and subsequent lines of each reference should be indented below the first line, by 7 mm.

If a reference ends in a URL, do not terminate it with a full stop.

The publisher name and the date of publication should be placed between parentheses and follow the book title. The place of publication should not be included. Do not insert a comma before the date: In *Digital transformation for business and society* (Routledge 2023).

References

Asmal, Z, Bhorat, H, Martin, LC & Rooney, C *Technological change in the insurance sector in South Africa* (DPRU Working Paper 202306, 2023).

Aspers, P & Corte, U 'What is qualitative in qualitative research?' (2019) https://link.springer.com/article/10.1007/s11133-019-9413-7

Bahri, ENA & Min, W 'Job creation vs job destruction following Industrial Revolution 4.0' in *Digital transformation for business and society* (Routledge 2023) 1–22.

Cooperative Governance and Traditional Affairs (CoGTA) 'Profile: OR Tambo District Municipality' (2020) https://www.cogta.gov.za

Jabbari, J, Zheng, H, Roll, S, Auguste, D & Heller, O 'How did reskilling during the COVID-19 pandemic relate to entrepreneurship and to optimism? Barriers, opportunities, and implications for equity' 2023 *Journal of Family and Economic Issues* 1–20.

Jeni, FA 'The impact of training and development on employee performance and productivity: An empirical study on private bank of Noakhali region in Bangladesh' (2021) https://www.researchgate.net/publication/352816350

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Xu, M, David, JJ & Kim, SH 'The Fourth Industrial Revolution: Opportunities and challenges' (2018) 9(2) *International Journal of Financial Research* 1923–4031.

Other key points

A would-be contributor is urged to comply with the following requests:

1. The body of the text should be in Times New Roman, 12 font, one-and-a-half line spacing.
2. Avoid unnecessary use of punctuation marks in both the text and footnotes. Thus: 'Ibid' not 'Ibid.'; 'Mr' not 'Mr.'; 'Doc' not 'Doc.'; 'No' not 'No.'; 'Alan EF Jones' not 'Alan E.F. Jones'.

3. Short quotations (up to 29 words) are to be included within the text; long quotations (30+ words) are normally to begin on a new line, to be indented 1,25 mm, 11 font, single spacing, not between quotation marks.
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