

## Original Research Article

### PHYSICO FUNCTIONAL AND NUTRITIONAL PROPERTIES OF NIXTAMILIZED FOXTAIL MILLET FLOUR

#### Abstract

**Aims:** To investigate the physico-functional and nutritional properties of nixtamalized foxtail millet and compare them with non-nixtamalized millet. Nixtamalization is an ancient processing technique involving the soaking and cooking of grains in an alkaline solution, typically lime water. This process enhances the nutritional profile, flavor, and functional properties of grains, making them more suitable for various culinary applications. Minor millets possess immense nutritional value, comparable to that of wheat, rice, and maize.

**Study design:** Experimental design

**Place and Duration of Study:** Foxtail millet grain and maize grain were procured from Millet Processing and Incubation Centre (MPIC) PJTSAU, Rajendranagar, Hyderabad and food grade calcium hydroxide chemical was purchased from local market in Hyderabad. This study was concluded during 2023

**Methodology:** Maize grain (TNM) and foxtail millet (TNF) were nixtamalized and analyzed for physical parameters viz. thousand kernel weight, thousand kernel volume and bulk density. Functional properties of nixtamalized grains such as swelling power, swelling capacity water solubility index, water holding capacity, oil absorption capacity; water absorption capacity and oil retention capacity and nutritional properties like moisture, fat, ash, crude fibre, carbohydrates, protein, energy

**Results:** It was found that physical parameters viz. thousand kernel weight, thousand kernel volume and bulk porosity decreased in nixtamalized grains. Functional properties of nixtamalized grains such as Swelling power, water solubility index, water holding capacity oil absorption capacity; water absorption capacity and oil retention capacity also increased significantly ( $p \leq 0.05$ ) and swelling significantly decreased in nixtamalized grains. Significant increase ( $p \leq 0.05$ ) in moisture TNM (34.31%) TNF3 (27.51%), ash content TNM (49.61%) TNF3 (2.37%), carbohydrate content (2.35%) TNF3 (2.10%) and fat content TNM (35.85%) TNF3 (26.30%), crude fibre TNM (26.35%) TNF3 (29.22%), energy (3.2%) TNM, TNF3 (3.56%) in nixtamalized grains was observed while protein value of nixtamalized grains were significantly lower TNM (11.76%) TNF3 (6.50%) compared to untreated grains.

**Key words:** Nixtamalization, foxtail millet, physical properties, functional properties, Nutritional properties

#### Introduction

Millets are highly nutritious, yet they have traditionally been overlooked as a primary food source. However, with increased research, their beneficial health effects have become more evident, and

they have gained significant importance in biomedical research (Bhat *et al.*, 2018). Millets provide numerous nutritional and medicinal benefits and serve as a major source of energy and protein for people in underdeveloped countries (Belton *et al.*, 2002).

Foxtail millet (*Setaria italica* L.) is one of the oldest cultivated crops, widely grown in the arid and semi-arid regions of Asia and Africa. It is also cultivated in some economically developed countries, and considered to be one of the world's highly productive major cereals (Wet *et al.*, 2023; Sharma & Niranjana 2018). Foxtail millets yield 351 kcal of energy per 100.0 g sample and contained 12.3 g protein, 60.9 g carbohydrates, 4.3 g fat, 8.0 g crude fibre, and 3.3 g of minerals and also it contains high amounts of protein, trace elements, vitamins, and antioxidants (Muthamilarasamet *al.* 2016) Anti-nutrients can be reduced through various treatment methods such as nixtamalization soaking, germination/sprouting, cooking, malting, and fermentation of the grains (Hassan *et al.*, 2023)

Nixtamalization, is a pre-treatment method in the tortilla industry, is an ancient technique for processing corn that is extensively used in many countries, particularly in Central America. This process is known to enhance the nutritional value of maize by improving protein quality, increasing the bioavailability of calcium and niacin, and reducing phytic acid levels, which in turn boosts iron digestibility and bioavailability (Owusu-Kwarteng *et al.*, 2013). Cooking maize in an alkaline solution softens the kernels and modifies their grain structure, thereby releasing bound nutrients and making them more accessible for the body to utilize upon consumption (Sunico *et al.*, 2021). Nixtamalization induces several physicochemical changes in maize kernels, improves flavor, and reduces mycotoxin levels in the final product (Matendo *et al.*, 2023).

Systematic research on the effects of nixtamalization treatments on flour quality is limited in foxtail millet. Thorough studies on how different treatments impact the nutritional, physical, and functional properties of flour are needed before incorporating them as ingredients in foods and developing them into value-added products with potential health benefits. In this content the foxtail millet was nixtamalized and all the analysis were performed to see the changes in physico-functionality of foxtail millet flour and compared with popular nixtamalized maize flours.

## **Material and methods**

### **Procurement of raw materials**

Foxtail millet grain and maize grain were procured from Millet Processing and Incubation Centre (MPIC) PJTSAU, Rajendranagar, Hyderabad and food grade calcium hydroxide chemical was purchased from local market in Hyderabad.

**Preparation of maize masa by nixtamalization:** The masa with maize was prepared by modified method of Owusu-Kwarteng *et al.* (2014). The maize grains ( 500 grams) was treated with 1.5% alkaline solution, adding 300 ml of water and pressure cooked for 20 mins, then

cooked grains were soaked for 20 hours. The nixtamalized grains were then washed to remove pericarp.

**Dry masa flour:** The nixtamalized grains were coarsely ground and dried in the tray dryer at the temperature between 35-40°C for 12-14 hours to obtain a moisture content of 9-10%. The material is then ground in Nisa mini flour mill to get fine and coarse flour.

**Preparation of foxtail masa by nixtamalization:** The masa with foxtail millet grain was prepared by modified method of Chhabra *et al.* (2017). The foxtail grains (500 grams) were treated with a 1.5% alkaline solution, and pressure cooked for only 5 minutes, followed by soaking for 1 hour. The nixtamalized grains were then washed to remove the pericarp. Despite these adjustments, the pericarp was not properly removed. Increasing the soaking time to 2 hours resulted in a slight improvement in pericarp removal. Finally, extending the soaking time to 3 hrs further allowed the pericarp to be properly removed. Increase of soaking time more than 3 hours was resulted in poor quality of flour.

**Dry masa flour:** The nixtamalized foxtail grains were coarsely ground and dried in the tray dryer at the temperature between 35-40°C for 12-14 hours to obtain a moisture content of 9-10%. The material is then ground in Nisa mini flour mill to get fine and coarse flour. Nonnixtamalized grain flours of maize and foxtail millet were taken as control samples.

**Physical Properties:** Physical properties of grains are of paramount importance in all the activities of production, preservation and utilization. Knowledge of physical properties is necessary right from harvesting, drying, handling and storage to milling, packing, cooking, product development and utilization. Foxtail millet and maize were grains measured for their physical properties viz., Thousand grain weight (AACC 1984) Thousand grain volume (AACC 1984) and Bulk density (Stojceska *et al.*, 2008).

**Functional properties:** The swelling capacity was determined according to the procedure of Arivuchudar and Aditi (2018). Swelling power (SP) and water solubility index (WSI) water absorption capacity (WAC) (Awoyale *et al.* 2020) Oil Retention Capacity (ORC) (Maxwell Beugre *et al.*, 2014), Water Holding Capacity (WHC) (Mesias and Morales, 2017) Oil absorption capacity (Sharma *et al.*, 2004 and Sairam *et al.*, 2011) were assessed for both nixtamalized and non nixtamalized maize flours.

**Nutritional parameters:** Best accepted nixtamalized maize grain, foxtail millet samples were analysed for proximates i.e., moisture (AOAC, 2005), ash (AOAC, 2005), protein (AOAC, 2010), fat (AOAC, 2005), carbohydrate (AOAC, 2006), energy (AOAC, 1980) and crude fibre (AOAC, 1995),

## Results and discussion

**Table 1: Physical properties of nixtamalized maize and foxtail grains**

Sample	Physical properties		
	Bulk density	Thousand grain wt ( g )	Thousand grain volume ( ml )
NNM	0.17 <sup>b</sup> ± 0.10	299.23 <sup>a</sup> ± 4.23	218.0 <sup>a</sup> ± 2.12
TNM	0.18 <sup>a</sup> ± 3.39	215.7 <sup>b</sup> ± 1.14	199.06 <sup>b</sup> ± 0.3
NNF	0.19 <sup>d</sup> ± 0.00	2.90 <sup>c</sup> ± 0.01	3.88 <sup>c</sup> ± 0.02
TNF1	0.18 ± 3.39	1.18 ± 0.00	2.33 ± 0.00
TNF2	0.18 ± 3.39	1.92 ± 0.02	2.83 ± 0.02
TNF3	0.20 <sup>c</sup> ± 3.39	2.41 <sup>d</sup> ± 0.00	2.90 <sup>d</sup> ± 0.01
mean	0.1799	0.163	0.095
S.E	0.0012	0.0013	0.002
C.D	0.00042	0.0003	0.004
C.V %	0.131	0.00	0.001

**Note:** values were expressed as mean ± standard deviation of three determinations

NNM: None treated nixtamalized maize

TNM: Treated nixtamalized maize

NNF: None treated nixtamalized foxtail

TNF1: Treated nixtamalized foxtail at 1hour

TNF2: Treated nixtamalized foxtail at 2hour

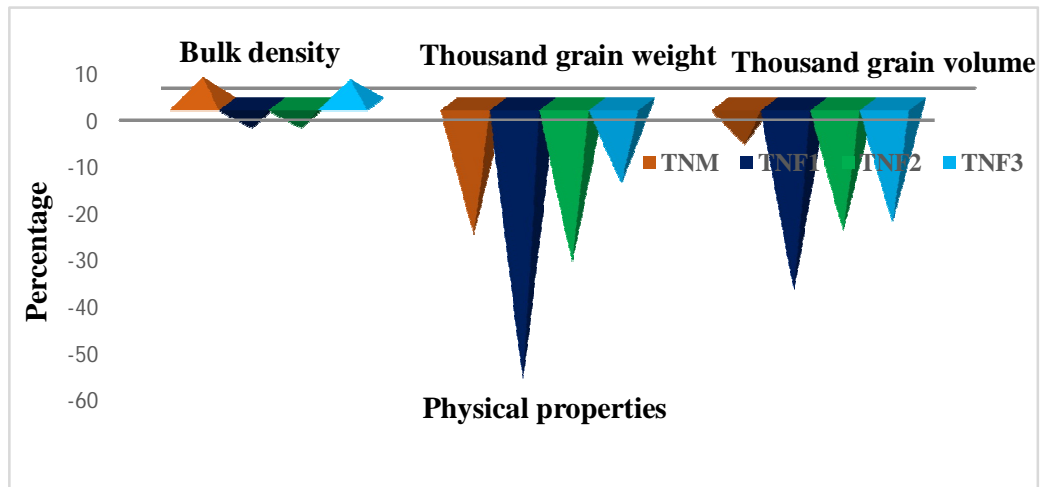
TNF3: Treated nixtamalized foxtail at 3hour

**Bulk density:** The bulk density of nixtamalized maize flour (0.18 g/ml) was significantly higher ( $p \leq 0.05$ ) than non-treated maize flour (0.17 g/ml). Significant differences ( $p \leq 0.05$ ) were observed among the bulk density of NNF (0.19 ± 0.00%), TNF1 (0.18 ± 3.39%), TNF2 (0.18 ± 3.39%), and TNF3 (0.20 ± 3.39%). TNF1 and TNF2, had a 5.2 % lower bulk density than NNF. TNF3 had 5.3% higher bulk density than NNF (Figure1).

**Thousand grain weight:** The thousand grain weight of nixtamalized maize (TNM) (215.7±1.14%) was significantly lower than non-nixtamalized maize (NNM) (299.23±4.23%), showing a 27.91% decrease due to nixtamalization. Vandana and Srivastava (2019) reported similar results, attributing the decrease to pericarp loss during lime treatment. TNF1 (1.18±0.0%), TNF2 (1.92±0.02%), and TNF3 (2.41±0.05%) also showed significant decreases in thousand grain weight compared to NNF (2.90±0.5%), with reductions of 59.31%, 33.79%, and 16.83%, respectively. With increased soaking time the thousand grain weight was reduced.

**Thousand grain volume:** The results demonstrated that non nixtamalized maize (NNM) had a significantly more thousand grain volume (218±2.12%) compared to the nixtamalized maize (TNM) (199.06±0.3 %). Thousand grain volume of TNM was decreased by 8.68 % when compare to NNF. Vandana and Srivastava (2019) reported that the thousand grain volume untreated nixtamalized grain was 220 ± 2.0% and thousand grain volume of nixtamalized grain was 200.3 ± 0.6 %. The thousand grain volume of TNF1 (2.33±0.09 %), TNF2 (2.83±0.02 %), and TNF3 (2.90±0.01 %) also showed significant differences ( $p \leq 0.05$ ) among the samples. The

thousand grain volume was 39.94 % less in TNF1, 27.06 % less in TNF2 and 25.25 % less in TNF3 when compared with NNF (Figure1).



**Fig. 1. Percentage change in physical properties of nixtamalized maize and foxtail grains when compared to control**

**Note:**  
TNM : Treated nixtamalized maize  
TNF1 : Treated nixtamalized foxtail at 1 hour  
TNF2 : Treated nixtamalized foxtail at 2hour  
TNF3 : Treated nixtamalized foxtail at 3 hour

**Table: 2 Functional properties of nixtamalized maize and foxtail flours**

Sample	Functional properties						
	SP	SC	WSI	WHC%	WAC%	ORC%	OAC%
NNM	233.96 <sup>b</sup> ± 6.45	1.08 <sup>b</sup> ± 0.00	1.80 <sup>b</sup> ± 0.00	141.41 <sup>b</sup> ± 9.43	2.25 <sup>b</sup> ± 0.10	1.56 <sup>b</sup> ± 0.16	3.03 <sup>a</sup> ± 0.16
TNM	255.20 <sup>a</sup> ± 5.06	1.186 <sup>a</sup> ± 0.00	2.94 <sup>a</sup> ± 0.00	167.20 <sup>a</sup> ± 71.20	2.67 <sup>a</sup> ± 0.11	2.160 <sup>a</sup> ± 0.58	3.52 <sup>b</sup> ± 0.39
NNF	188.82 <sup>d</sup> ± 23.10	1.07 <sup>d</sup> ± 0.00	1.39 <sup>d</sup> ± 0.14	80.16 <sup>d</sup> ± 6.75	1.34 <sup>d</sup> ± 0.87	2.11 <sup>d</sup> ± 0.36	1.69 <sup>d</sup> ± 0.66
TNF1	208.52 ± 1.66	1.053 ± 0.00	1.41 ± 0.16	114.30 ± 2.31	2.04 ± 0.40	2.80 ± 0.02	2.02 ± 0.04
TNF2	221.69 ± 2.15	1.086 ± 0.01	1.96 ± 0.01	164.69 ± 1.62	2.23 ± 0.13	2.86 ± 0.48	2.18 ± 0.0
TNF3	228.01 <sup>c</sup> ± 2.42	1.093 <sup>c</sup> ± 0.00	2.08 <sup>c</sup> ± 0.01	191.51 <sup>c</sup> ± 23.56	2.24 <sup>c</sup> ± 0.19	2.87 <sup>c</sup> ± 0.21	2.4 <sup>c</sup> ± 0.184
Mean	222.70	1.0949	1.9322	143.2	2.212	2.398	2.49
S.E	5.3966	0.0105	0.1271	10.85	0.1135	0.1308	0.164
C.D	17.999	0.0120	0.1618	55.15	0.463	0.484	0.594
C.V %	4.543	0.618	4.707	21.647	12.259	11.349	13.431

**Note:**  
were

values

SP: Swelling Power

NNM: None treated nixtamalized maize

SC : Swelling capacity

TNM: Treated nixtamalized maize

WSI : Water solubility index

NNF: None treated nixtamalized foxtail

WHC : Water holding capacity

TNF1: Treated nixtamalized foxtail at 1hour

WAC : Water absorption capacity

TNF2: Treated nixtamalized foxtail at 2hour

ORC : Oil retention capacity

TNF3: Treated nixtamalized foxtail at 3hour

(OAC : Oil absorption capacity

expressed as mean ± standard deviation of three determinations

UNDER PEER REVIEW

**Functional properties of nixtamalized maize flours:** Maize grain and foxtail was powdered and functional properties were measured. The results were measured statistically and presented in Table 2 and Figure 2.

**Swelling power:** The results showed that TNM had more ( $255.20 \pm 5.06$ ) SP than NNM ( $233.96 \pm 6.45$ ). The results indicated that, swelling power of nixtamalized maize grain was significantly ( $p \leq 0.05$ ) more when compared to non nixtamalized maize. There was increased in 9.07 % of swelling power in NM when compared to control NNM (Figure 2). The swelling power of TNF1 ( $208.52 \pm 1.66$ ), TNF2 ( $221.69 \pm 2.15$ ), TNF3 ( $228.01 \pm 2.42$ ) were significantly higher, by 10.43 %, 17.40 % and 20.7 % respectively compared to NNF (Figure 2).

**Swelling capacity:** The swelling capacity of nixtamalized maize (TNM) had a more swelling capacity ( $1.186 \pm 0.001$ ) compared to non – nixtamalized maize (NNM) ( $1.08 \pm 0.00$ ). The swelling capacity of nixtamalized maize was significantly greater ( $p \leq 0.05$ ) with an increase of 9.81 % compared to the control (NNM) (Figure 2). The Swelling capacity of TNF1 ( $1.053 \pm 0.00$ ), TNF2 ( $1.086 \pm 0.001$ ) TNF3 ( $1.093 \pm 0.00$ ) also showed significant difference among the samples. The swelling capacity decreased (1.58%) in TNF1 and 1.49 % increase in TNF2 and 1.86 % increased in TNF3 when compared to NNF (Figure 2). Flours with high swelling capacity indicate improved functionality, leading to a superior final product (Adebiyi *et al.*, 2016)

**Water solubility index:** It was found that nixtamalized maize (TNM) had a higher water solubility index (WSI) ( $2.94 \pm 0.00$ ) compared to non-nixtamalized maize (NNM) ( $1.80 \pm 0.00$ ), with an increase of 63.3%. The WSI values for NNF ( $1.39 \pm 0.14$ ), TNF1 ( $1.413 \pm 0.168$ ), TNF2 ( $1.96 \pm 0.01$ ), and TNF3 ( $2.08 \pm 0.01$ ) showed significant differences ( $p \leq 0.05$ ). TNF1 had a 1.65% higher WSI than NNF, TNF2 had a 41.00% increase, and TNF3 had a 49.64% WSI compared to NNF.

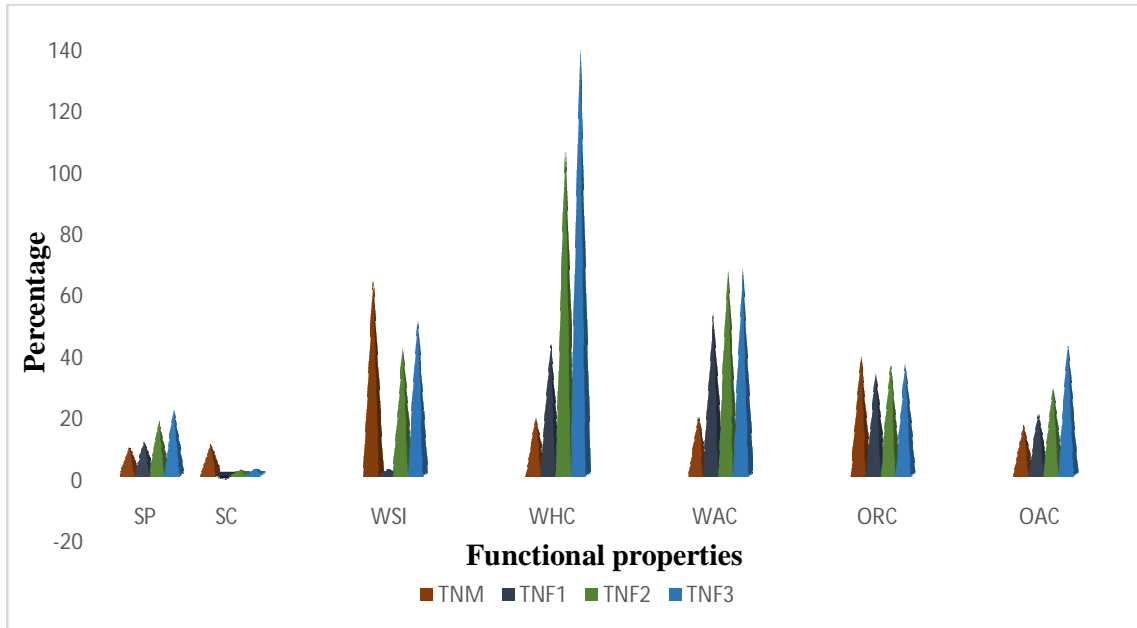
**Water holding capacity:** Nixtamalized maize (TNM) had a significantly higher water holding capacity (WHC) of ( $167.20 \pm 71.20$ ) compared to non- nixtamalized maize (NNM) at ( $141.41 \pm 9.430$ ). There was an increase (18.23 %) (Figure 2) of water holding capacity of nixtamalized maize with respect to control. Significant differences in WHC were observed among NNF ( $80.16 \pm 6.75$ ) TNF1 ( $114.3 \pm 2.31$ ), TNF2 ( $164.69 \pm 1.62$ ), and TNF3 ( $191.51 \pm 23.56$ ). TNF1, TNF2 and TNF3 showed increase of 42.52 %, 105.45 % 138.90 % in WHC compared to NNF, respectively.

**Water absorption capacity:** The WAC subjectively measures the amount of water absorbed by the flour during masa preparation. The water absorption capacity (WAC) of nixtamalized maize (TNM) was  $2.67 \pm 0.11$ , significantly higher than the control ( $2.25 \pm 0.10$ ), with an 18.6% increase. Significant differences ( $p \leq 0.05$ ) in WAC were observed among NNF ( $1.34 \pm 0.87$ ), TNF1 ( $2.04 \pm 0.40$ ), TNF2 ( $2.23 \pm 0.13$ ), and TNF3 ( $2.24 \pm 0.19$ ). TNF1, TNF2, and TNF3 had WACs 52.08%, 66.41%, and 67.16% higher than NNF, respectively. The improved water

absorption capacity of treated flours is crucial for food applications, as it enhances mouthfeel and flour retention (Adebisi *et al.*, 2016)

**Oil retention capacity** The data showed that nixtamalized maize (NM) had a higher oil retention capacity ( $2.160 \pm 0.58$ ) compared to non-nixtamalized maize (NNM) ( $1.56 \pm 0.16$ ), with a 38.46% increase ( $p \leq 0.05$ ). Significant differences ( $p \leq 0.05$ ) were observed in the oil retention capacity among NNF ( $2.11 \pm 0.36$ ), TNF1 ( $2.80 \pm 0.02$ ), TNF2 ( $2.86 \pm 0.48$ ), and TNF3 ( $2.87 \pm 0.21$ ). TNF1, TNF2, and TNF3 had 32.54%, 35.54%, and 36.01% higher oil retention capacities than NNF, respectively.

**Oil absorption capacity:** The results showed that nixtamalized maize (NM) had a significantly higher oil absorption capacity ( $3.52 \pm 0.39$ ) than non-nixtamalized maize (NNM) ( $3.03 \pm 0.16$ ), with a 16.17% increase ( $p \leq 0.05$ ). Additionally, significant differences ( $p \leq 0.05$ ) were found in the oil absorption capacities of NNF ( $1.69 \pm 0.66$ ), TNF1 ( $2.02 \pm 0.04$ ), TNF2 ( $2.18 \pm 0.0$ ), and TNF3 ( $2.4 \pm 0.184$ ). TNF1, TNF2, and TNF3 had 19.52%, 28.99%, and 42.02% higher oil absorption capacities than NNF, respectively. Oil absorption capacity measures how well proteins bind to fats in food formulations, enhancing the mouthfeel and flavor of food products by absorbing fat or oil (Ekwe and Ihemeje, 2013)



**Fig. 2. Percentage change in functional properties of nixtamalized maize and foxtail flours when compared to control**

Note: SP : Swelling power  
 SC : Swelling capacity  
 WSI : Water solubility index  
 WHC : Water holding capacity  
 WAC : Water absorption capacity  
 ORC : Oil retention capacity  
 OAC ; Oil absorption capacity

TNM) : Treated nixtamalized maize  
 TNF1 : Treated nixtamalized foxtail at 1 hour  
 TNF2 : Treated nixtamalized foxtail at 2hour  
 TNF3 : Treated nixtamalized foxtail at 3 hour

Samples	Nutritional properties						
	Moisture %	Fat %	Crude fibre %	Ash %	Protein %	CHO %	Energy K cal/ 100g
<b>NNM</b>	4.08 <sup>b</sup> ± 0.076	2.54 <sup>b</sup> ± 0.147	1.46 <sup>b</sup> ± 0.12	1.29 <sup>b</sup> ± 0.03	9.52 <sup>a</sup> ± 0.11	80.55 <sup>b</sup> ± 0.01	354 <sup>b</sup> ± 0.00
<b>T NM</b>	5.50 <sup>a</sup> ± 0.346	3.96 <sup>a</sup> ± 0.075	1.87 <sup>a</sup> ± 0.03	1.93 <sup>a</sup> ± 0.04	8.40 <sup>b</sup> ± 0.78	82.46 <sup>a</sup> ± 0.14	366 <sup>a</sup> ± 0.00
<b>NNF</b>	5.67 <sup>d</sup> ± 0.256	3.65 <sup>d</sup> ± 0.221	2.19 <sup>d</sup> ± 0.015	3.37 <sup>d</sup> ± 0.01	11.06 <sup>c</sup> ± 0.23	74.35 <sup>d</sup> ± 0.25	375 <sup>d</sup> ± 0.00
<b>TNF3</b>	7.23 <sup>c</sup> ± 0.115	4.61 <sup>c</sup> ± 0.102	2.83 <sup>c</sup> ± 0.03	3.45 <sup>c</sup> ± 0.0	10.34 <sup>d</sup> ± 0.02	76.36 <sup>c</sup> ± 0.10	388 <sup>c</sup> ± 0.00
<b>Mean</b>	5.59	3.692	2.0958	2.2842	9.833	78.431	0..00
<b>S.E</b>	0.3410	0.2292	0.1506	0.2726	0.3154	0.973	0.045
<b>C.D</b>	0.4247	0.277	0.123	0.187	0.775	0.2984	0.00
<b>C.V %</b>	4.028	3.989	3.120	4.017	4.188	0.202	0.02

**Table. 3. Nutritional properties of nixtamalized maize and foxtail flour**

Note ;  
 NNM : Non treated nixtamalized maize  
 TNM : Treated nixtamalized maize  
 NNF : Non treated nixtamalized foxtail  
 TNF3 : Treated nixtamalized foxtail at 3 hour

### Proximate composition of nixtamalized and non nixtamalized flours

**Moisture:** Moisture content of TNM was  $5.50 \pm 0.346\%$ , which was significantly ( $p < 0.05$ ) more than the NNM sample ( $4.08 \pm 0.076\%$ ). The moisture of TNM was 34.31% more than NNM. The findings of Matendo *et al.* (2019) showed that moisture content of nixtamalized maize grain was  $5.6 \pm 0.34\%$  and untreated grain  $4.2 \pm 0.17\%$ . The moisture content of NNF was  $5.67 \pm 0.256\%$  and TNF3 was  $7.23 \pm 0.115\%$ . The moisture content of TNF3 was 27.51 % increased than NNF (Figure3).

**Fat:** The fat content of nixtamalized maize (TNM) was significantly higher ( $3.96 \pm 0.07\%$ ) compared to non-nixtamalized maize (NNM) ( $2.54 \pm 0.147\%$ ), with a 35.85% increase ( $p \leq 0.05$ ). Matendo *et al.* (2019) reported that fat content of nixtamalized maize grain was  $3.77 \pm 0.1\%$  and untreated grain  $2.57 \pm 0.2\%$ . TNF3 had a significantly higher fat content ( $4.61 \pm 0.102\%$ ) than NNF ( $3.65 \pm 0.221\%$ ), showing a 26.30% increase.

**Ash:** NNM and TNM showed significant difference ( $p < 0.05$ ) in ash content. The ash content of TNM ( $1.93 \pm 0.04\%$ ) is greater than NNM with  $1.29 \pm 0.03\%$  (Table 3). On comparison with control TNM had 49.61% more ash content. Matendo *et al.* (2019) showed that ash content of nixtamalized maize grain was  $1.97 \pm 0.0\%$  and untreated grain  $1.28 \pm 0.02\%$ . Ash content of TNF3 was  $3.45 \pm 0.0\%$  which was significantly ( $p < 0.05$ ) more than the NNF sample ( $3.37 \pm 0.01\%$ ). The ash content of TNF3 was 2.37% more than NNF.

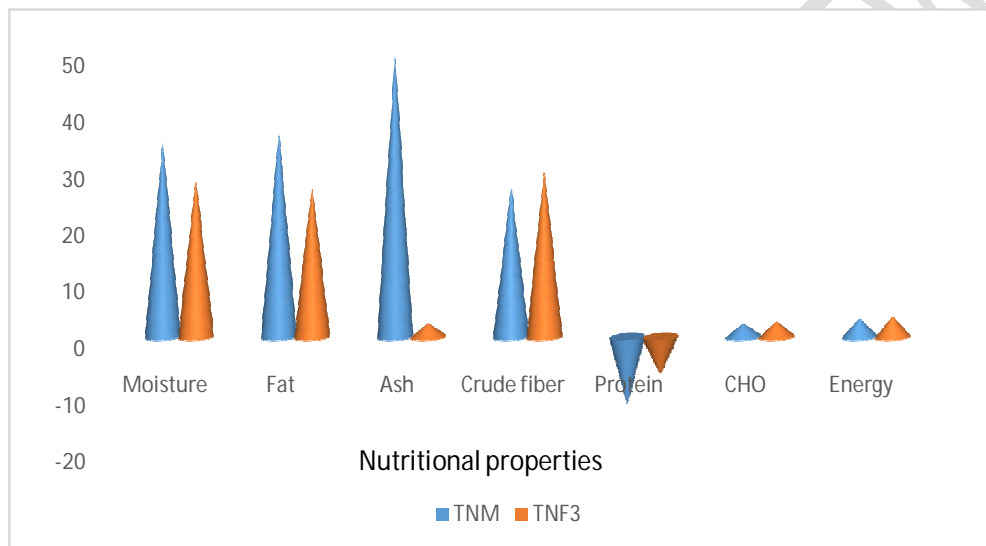
**Crude fibre:** The crude fibre content of TNM had ( $1.87 \pm 0.03\%$ ) is greater than NNM with ( $1.46 \pm 0.12\%$ ) (Table 3). On comparison with control TNM had 26.35 % more crude fibre content. Matendo *et al.* (2019) reported that crude fibre of nixtamalized maize grain was  $1.86 \pm 0.5\%$  and untreated grain  $1.48 \pm 0.2\%$ . Crude fibre content of TNF3 was  $2.83 \pm 0.3\%$ , which was significantly ( $p < 0.05$ ) more than the NNF sample ( $2.19 \pm 0.015\%$ ). Increase 29.22% in TNF3 than NNF.

**Protein:** NNM and TNM showed significant difference ( $p < 0.05$ ) in protein content. NNM had 11.76 % more protein content than TNM. Matendo *et al.* (2019) showed that protein content of nixtamalized maize grain was  $9.01 \pm 0.7\%$  and untreated grain  $9.48 \pm 0.3\%$ . Protein content of TNF3 was  $10.34 \pm 0.02\%$ , which was lower than the NNF sample ( $11.06 \pm 0.23\%$ ). The protein content of TNF3 was 6.50 % lower than NNF.

**Carbohydrate:** The carbohydrate content of nixtamalized maize (TNM) ( $82.46 \pm 0.14\%$ ) was significantly higher ( $p < 0.05$ ) than that of non-nixtamalized maize (NNM) ( $80.55 \pm 0.14\%$ ), with a 2.35% increase due to nixtamalization. Matendo *et al.* (2019) reported carbohydrate contents of  $77.06 \pm 7.0\%$  for nixtamalized maize and  $74.43 \pm 6.2\%$  for untreated grain. TNF3 had a

carbohydrate content of  $76.36 \pm 0.10$ , significantly higher ( $p < 0.05$ ) than NNF ( $74.35 \pm 0.25$ ), representing a 2.10% increase.

**Energy:** The energy content of TNM had ( $366 \pm 0.03$  Kcal/100g) is greater than NNF with ( $354 \pm 0.12$  Kcal/g) (Table 3). On comparison with control TNM had 3.2 % more energy content may be due to nixtamalization. Matendo *et al.* (2019) reported similar findings, energy of nixtamalized maize grain was  $366 \pm 2.7$  Kcal/g and untreated grain  $354 \pm 3.2$  Kcal/100g. Energy content of TNF3 was  $388 \pm 0.04$  Kcal/100g, which was significantly ( $p < 0.05$ ) more than the NNF sample ( $375 \pm 0.01$  Kcal/100g). The energy content of TNF3 was 3.56% more than NNF



**Fig. 3. Percentage change in nutritional properties of nixtamalized maize and foxtail flours when compared to control**

Note: **TNM:** Treated nixtamalized maize  
**TNF3:** Treated nixtamalized foxtail at 3 hours

**Conclusion:** In the present study physico functional and nutritional properties of nixtamalized foxtail flour was studied. It was found that physical parameters viz. thousand kernel weight, thousand kernel volume and bulk porosity decreased in nixtamalized grains. Functional properties of nixtamalized grains such as Swelling power, water solubility index, water holding capacity, oil absorption capacity; water absorption capacity and oil retention capacity also increased significantly ( $p \leq 0.05$ ) and swelling capacity significantly decreased in nixtamalized flours. Significant increase ( $p \leq 0.05$ ) in moisture, ash content, carbohydrate content and fat content,

crude fibre energy nixtamalized flours was observed while protein value of nixtamalized flours were significantly lower compared to untreated flours. Flours with high WAC are suitable for incorporation into food formulations, especially in those involving dough. Consuming meals made from lime-treated millet flour is more beneficial in terms of nutrients compared to untreated millet flour. Nixtamalized foxtail millet exhibits enhanced physico-functional and nutritional properties, making it a valuable ingredient for various food products. The process of nixtamalization improves nutrient availability, digestibility, texture, and flavor. This leads to superior quality in a range of products, including breads, porridges, snacks, baked goods, pasta, extruded items, beverages, infant foods, traditional dishes, and tortilla chips. The importance of nixtamalized foxtail millet lies in its ability to provide a nutritionally enriched and versatile option for food innovation, contributing to the development of healthier and better-tasting products.

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