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Abayomi (2000), Agindotan et al. (2003), (Kelebeni, 1983), (Usman and Smith, 1992), (Chege, 1998;

1987a,b; Tijani, 1993,1995), (Kumasi et al., 2001) References should be listed at the end of the paper in alphabetical order. Articles in preparation or articles submitted for publication, unpublished observations, personal communications, etc. should not be included in the reference list but should only be mentioned in the article text (e.g., A. Kingori, University of Nairobi, Kenya, personal communication). Journal names are abbreviated according to Chemical Abstracts. Authors are fully responsible for the accuracy of the references.

Examples:

Chikere CB, Omoni VT and Chikere BO (2008). Distribution of potential nosocomial pathogens in a hospital environment. *Afr. J. Biotechnol.* 7: 3535-3539.

Moran GJ, Amii RN, Abrahamian FM, Talan DA (2005). Methicillinresistant *Staphylococcus aureus* in community-acquired skin infections. *Emerg. Infect. Dis.* 11: 928-930.

Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing *Escherichia coli* in the Calgary Health Region: emergence of CTX-M-15-producing isolates. *Antimicrob. Agents Chemother.* 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). *Microbiology: Concepts and Applications.* McGraw-Hill Inc., New York, pp. 591-603.

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## Review

# Economic implication of industrialization of a popular weaning food “ogi” production in Nigeria: A review

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**Socio-economic relevance of fermented food in developing countries is evident. However, the production of this category of food is still achieved under primitive conditions. Ogi a fermented product from maize, sorghum or millet is usually transformed into gruel or porridge when heated. About a quarter of Nigeria population is said to consume Ogi on a weekly bases. This coupled with increasing industrialization and urbanisation in the country may however dictate the need for large-scale production of Ogi. The proposal for industrialisation of this process will lead to a deliberate and calculated combination of chemical or mechanical steps to aid the manufacture of this product. However, the growth of small-scale or large industries for this product may be confronted with some limiting factors prevalent in most third world countries. Ogi production have some similarities in unit operations when compared with corn starch production, therefore the same technologies may be adopted with appropriate modification in the production of Ogi and this will provide employment to a number of people. This review is with a view to establish the need to mechanise the process and as well as point out the technological and economical implication.**

**Key words:** Ogi, biotechnology, upgrading potentials, industrialization process, economical implication.

## INTRODUCTION

Ogi is a staple cereal fermentation product found predominantly in Southern Nigeria and is usually the first native food given to babies at weaning. It is produced generally by soaking maize grains in warm water for 2-3 days followed by wet milling and sieving through a screen mesh. Nnanyelugo and Onofiok (2004) reported the use of Ogi as a weaning food in western Nigeria to supplement breastfeeding between ages of 3-6 months. However; this may be inadequate to meet the nutritional demands of growing infants (Nnanyelugo and Onofiok, 2004). It

has also been shown that Ogi liquor has both anti-bacterial (Adebolu et al., 2007) and antifungal properties (Adebayo and Aderiye, 2010).

Ogi is usually prepared from fermented maize, sorghum or millet in West Africa (Akingbala et al., 1981). It is a popular breakfast cereal and infant weaning food in Nigeria (Akingbala et al., 1981; Banigo and Muller, 1972a, b; Adeyemi, 1983; Odunfa, 1985; Aworh, 2008). It can be diluted into solids content of 8 to 10% and boiled into a pap, or cooked and turned into a stiff gel called

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**Table 1.** Research studies\* on manufacturing/production/fermentation process of Ogi.

Author (year of publication)	Title
Akinrele (1966)	A biochemical study of the traditional method of preparation of Ogi and its effect on the nutritive value of corn.
Banigo (1969)	An investigation into the fermentation and enrichment.
Akinrele (1970)	Fermentation studies on sorghum during the preparation of a traditional African starch- cake food.
Banigo and Muller (1972a)	Manufacture of Ogi (A Nigeria fermented cereal porridge). Comparative evaluation of corn, sorghum and millet.
Banigo and Muller (1972b)	Carboxylic acid pattern in Ogi fermentation
Banigo et al. (1974)	Utilization of high lysine corn for the manufacture of "Ogi" using a new improved processing system.
Ekpenyoung et al. (1977)	Fortification of maize flour based diets with blends of cashew nut meal, African locust bean and sesame oil meal.
Olatunji (1977)	Production and utilization of local dry corn milled products in Nigeria.
Akingbala et al. (1981)	A laboratory procedure for the preparation of Ogi, a Nigerian fermented food.
Adeyemi, (1983)	Dry milling of sorghum for Ogi manufacture.
Akingbala et al. (1987)	Steeping of whole and dry milled maize kernels in Ogi preparation.
Okoli and Adeyemi (1989)	Manufacturing of Ogi from malted (germinated) corn ( <i>Zea mays</i> ): evaluation of chemical, pasting and sensory properties.
Adeyemo et al. (1992).	Biochemical analysis of germinating white maize ( <i>Zea mays</i> ).
Calderon et al. (2003)	Fermentation by <i>Lactobacillus fermentum</i> Ogi E1 of different combinations of carbohydrates occurring naturally in cereals: consequences on growth energetic and $\alpha$ -amylase production
Aminigo and Akingbala (2004)	Nutritive composition of Ogi Fortified with okra seed meal. .
Inyang and Idoko (2006)	Assessment of the quality of Ogi made from malted millet
Ojokoh (2009).	A comparative study on the effect of traditional and improved methods of fermentation in the production of Ogi food
Omemu and Adeosun (2010)	Evaluation of hazards and critical control points of Ogi in small scale processing centers in Abeokuta.

\*According to the year of publication.

"agidi" or "eko" before consumption (Odufa, 1985). This same product is often eaten along with meat, stew, vegetable soup, steamed bean cake ('moin-moin') or fried bean cake (Akara) (Igbodion et al., 1996). The economic strength of the consumers does influence the choice of the supplements (Teniola and Odufa, 2001). It has been established that substantial nutrient losses occur during the various stages of production of Ogi. These losses have been evaluated and reported by several workers (Oke, 1967; Banigo and Muller, 1972; Akingbala et al., 1981). A lot of modification has also been introduced into the process as shown in various studies (Tables 1, 2, 3, 4, 5 and 6). Onyekwere et al. (1989) gave a description of the traditional as well as the industrial production of Ogi. Various supplements of Ogi have been developed including: tempeh (Egounlety and Syarief, 1992), soybeans (Adeniji and Potter, 1978; Akinrele et al., 1970), pawpaw (Adeyemi and Soluade, 1993) and cowpea (Akoboundu and Hoskins, 1987; Ojofeitimi et al., 1984). Olukoya et al. (1994) reported the development of an Ogi product (dogik), which have therapeutic properties on the basis of its stability to control diarrhea among infants. Dehydration of Ogi by drum or tray drying was

reported to prolong shelf-life of Ogi (Adeniji and Potter, 1978). However, these dehydration methods were found to destroy heat-sensitive nutrients (Adeniji and Potter, 1978).

According to Aworh (2008), the capacity to preserve food is directly related to the level of technological development. The author also stressed that slow pace of upgrading traditional food processing and preservation techniques in West Africa contributes to food and nutrition insecurity in the sub-region. An appropriate transformation of these primitive techniques to modern or mechanized stand the chance of creating employment opportunities in the rural areas, reduce rural-urban migration and the associated social problems (Aworh, 2008). The same author also highlighted that the adoption of inappropriate technologies in food processing, poor management, inadequate working capital and limited access to funds and financial institution are limiting the required growth of small scale food industries in west African countries.

The traditional processing of Ogi often employ fermentation techniques that are characterized by the use of simple non-sterile equipment, introduction of natural

**Table 2.** Previous studies\* on Ogi fortification

Author (year of publication)	Title
Akinrele and Edwards (1971)	An assessment of the nutritive value of maize-soya mixture, soy-Ogi as a weaning food in Nigeria.
Adeyemi and Beckley (1986)	Effect of period of maize fermentation and souring on chemical properties and amylograph viscosity of Ogi.
Egounlety and Syarief (1992)	Study on supplementation of Ogi with Tempeh.
Olukoya et al. (1994)	Production of Dogik: an improved Ogi (a Nigerian fermented weaning food) with potential for use in diarrhea control.
Akingbala et al. (2005)	Effects of color and flavor changes on acceptability of Ogi supplemented with okra seed meals.
Oluwamukomi et al. (2005)	Effect of soy supplementation and its stage of inclusion on the quality of Ogi- a fermented maize meal.
Otunola et al. (1998)	Development and evaluation of maize-Tempeh mixes as an instant food product
Otunola et al. (2006)	Effect of addition of Tempeh on some properties of 'Agidi', a West African fermented maize gel.
Fasasi <sup>1</sup> et al. (2007).	Functional and pasting characteristics of fermented maize and Nile Tilapia ( <i>Oreochromis niloticus</i> ) flour diet.
Adejuyitan et al. (2012).	An evaluation of some properties of Baobab fruit powder and Ogi mixes
Aremu et al. (2011).	Biochemical evaluation of fermented white maize ( <i>Zea mays</i> L.) blended with scarlet runner bean ( <i>Phaseolus coccineus</i> L.) flour.
Ajanaku and Oluwole (2013)	Determination of nutritional content of sorghum-Ogi weaning food mixed with Crayfish ( <i>Paranephrops planifrons</i> )
Oluseyi et al. (2013)	Dietary fortification of sorghum-Ogi using Crayfish ( <i>Paranephrops planifrons</i> ) as supplements in infancy.

\*According to the year of publication.

**Table 3.** Previous studies\* on microbial significance in the processing of Ogi.

Author (year of publication)	Title
Akinrele et al. (1970)	The development and production of soy Ogi.
Onyekwere and Akinrele (1977)	Ogi, a Nigerian fermented maize beverage.
Odufa (1985)	African fermented foods.
Osungbaro (1990a)	Effect of differences in varieties and dry milling of maize on the textural characteristics of Ogi (fermented maize porridge) and Agidi (fermented maize meal).
Egounlety and Aworh (1991)	Production and physicochemical properties of tempeh-fortified maize based weaning foods.
Olasupo et al. (1997)	Identification of <i>Lactobacillus</i> species associated with selected African fermented foods.
Nago et al. (1998)	Characterization of Beninese traditional Ogi, fermented sorghum slurry: physicochemical and microbiological aspects.
Sanni et al. (2001)	Influence of processing conditions on the nutritive value of Ogi-Baba, Nigerian fermented sorghum gruel.
Teniola and Odufa (2003)	Microbial assessment and quality evaluation of Ogi during spoil age.
Ojo and Akanbi (2004)	Rheology of Soy-Ogi: Effect of concentration and temperature.
Omemu et al. (2007)	Significance of yeasts in the fermentation of maize for Ogi production.
Osungbaro (2009)	Physical and nutritive properties of fermented cereal foods
Wakil and Daodu (2007)	Physiological properties of a microbial community in spontaneous fermentation of maize ( <i>Zea mays</i> ) for Ogi production
Akinleye et al. (2014)	Evaluation of microorganisms at different stages of production of Ogi in Alimosho community, area South West, Lagos, Nigeria.

According to the year of publication.

inoculums, unregulated conditions, sensory fluctuations, poor durability and unattractive packing of the processed products which result in unpredictable quality of the product

(Olanrewaju et al., 2009; Oyewole and Isah2012). According to Agarry et al. (2010), with increasing industrialization and urbanization, efforts are presently

**Table 4.** Previous studies\* on antimicrobial influence of Ogi and Ogi by-product.

Author (year of publication)	Title
Adebolu et al. (2012)	Antibacterial activity of microorganisms isolated from the liquor of fermented maize Ogi on selected diarrheal bacteria.
Oluwafemi and Adetunji (2011).	Antimicrobial activities of lactic acid bacteria isolated from traditionally- fermented maize (Ogi) against <i>Candida albicans</i>
Onwuakor et al. (2014).	Effect of varied culture conditions on bacteriocin production of four <i>Lactobacillus</i> species isolated from locally fermented maize (Ogi).

\*According to the year of publication.

**Table 5.** Previous studies\* on improving indigenous fermented foods.

Author (year of publication)	Title
Okafor (1981)	A scheme for the improvement of fermented foods of Africa South of the Sahara in global impacts
Okafor (1983)	Processing of Nigerian indigenous fermented foods– A chance for innovation.
Onyekwere et al. (1989)	Industrialization of Ogi.
Sokari (1992)	Improving the nutritional quality of Ogi and Gari. Applications of biotechnology to traditional fermented foods.
Steinkraus (1996)	Indigenous fermented food involving an acid fermentation.

According to the year of publication.

**Table 6.** Previous studies\* on drying and storage of Ogi

Author (year of publication)	Title
Adeniji and Potter (1978).	Properties of Ogi powders made from normal fortified and opaque – 2-corn.
Achi (2005)	The potential for upgrading traditional fermented foods through biotechnology
Ohenhen and Ikenemoh (2007)	Shelf stability and enzyme activity studies of Ogi: A corn meal fermented product.
Afolayan et al. (2010)	An Investigation into sorghum based Ogi (Ogi-Baba) storage characteristics.
Bolaji et al. (2011a)	Effect of storage temperature on some Ogi properties
Bolaji et al. (2011b)	Evaluation of changes in pasting properties of Ogi during storage
Ladunni et al. (2013).	Effects of drying method on selected properties of Ogi (Gruel) prepared from sorghum ( <i>Sorghum vulgare</i> ), Millet ( <i>Pennisetum glaucum</i> ) and Maize ( <i>Zea mays</i> ).
Bolaji et al. 2014).	Mathematical modeling of drying pattern and thermal properties of Ogi produced from four maize varieties.
Bolaji et al. (2014)	Soaking and drying effect on the functional properties of Ogi produce from some selected maize varieties.
Bolaji (2015).	Mathematical modeling of drying pattern of Ogi produced From Two Types of Maize Grain.

According to the year of publication.

geared towards the development of large-scale factory production facilities for these foods where the quality of the finished product will be assured.

This review is with a view to establish the need to mechanise the process and as well as point out the technological and economical implication. The review looks at the past research efforts in Ogi production with a view to highlight area that requires improvement and recommends further studies that needs to be done

especially in dehydration on commercial production with focus on standardization of the process for commercial purposes.

### Historical evaluation of Ogi production

So many areas have been explored by many researchers with respect to quality, quantity and traditional and

modern method of Ogi production in the West African country (Tables 1 to 6). Previous studies in the production of Ogi were on fermentation process (Akinrele, 1970; Banigo et al., 1974; Akingbala et al., 1981; Banigo and Muller, 1972; Sokari, 1992), traditional and modern methods of production of "Ogi (Onyekwere et al., 1989), nutritional potentials (Akinrele, 1970; Oke, 1967; Banigo and Muller, 1972b; Akinrele and Bassir, 1967; Akinrele and Edwards, 1971; Fashakin and Ogunsola, 1982), chemical composition of Ogi (Banigo and Muller, 1972; Akinrele, 1970), social status of Ogi (Mensah et al., 1988; Igbedioh et al., 1996) and fortification (Egounlety and Syarief, 1992; Adeniji and Potter, 1978; Akanbi et al., 2003; Adeyemi and Soluade, 1993; Ojofeitimi et al., 1984; Olukoya et al., 1994). The use of high lysine corn for improving the nutritional value of Ogi was reported by Banigo et al. (1974) and microbial activities and involvement in the production of Ogi were reported by some researchers (Akingbala et al., 1981; Akoboundu and Hoskins, 1987; Akinrele, 1970; Odunfa and Adeyele, 1985; Olasupo et al., 1997; Teniola and Odunfa, 2002; Ogunbanwo et al., 2003a, 2003b). Inyang and Idoko (2006) studied the quality of Ogi made from malted millet. Microbiological and nutritional studies showed that the lactic acid bacterium, *Lactobacillus plantarum*, the aerobic bacteria *Corynebacterium* and *Aerobacter*, the yeasts *Candida mycoderma*, *Saccharomyces cerevisiae* and *Rhodotorula* and molds *Cephalosporium*, *Fusarium*, *Aspergillus* and *Penicillium* are the major organisms responsible for the fermentation of Ogi (Akinrele, 1970). Odunfa and Adeyele (1985) found that *L. plantarum* was the predominant organism in the fermentation responsible for lactic acid production. Ogunbanwo et al. (2003a), worked on characterization of bacteriocin produced by *Lactobacillus plantarum* F1 and *Lactobacillus brevis* OG1 and Ogunbanwo et al. (2003b) determined the influence of cultural conditions on the production of bacteriocin by *Lactobacillus brevis* OG1.

## POTENTIAL PROCESS CHALLENGES IN THE COMMERCIAL PRODUCTION OF OGI

Despite exploration of all these areas in the production of Ogi, the changes induced by the soaking period and processes on engineering properties (physical, mechanical, rheological, thermal and structural properties) are very scanty in the literature. These may be necessary in standardization of the industrial process. It should be noted that soaking, milling, sieving and heat application are necessary in the production of Ogi and subsequent products. Furthermore, this information will be relevant in design of equipment and the process necessary in the optimization and standardization of commercial Ogi production (Bolaji, 2014). The knowledge gleaned from such endeavor may be used to determine the optimal processing conditions. The standardization of the process

will be necessary in commercial production of Ogi and will help in determining the minimum time and energy required in the production process. The amount of water necessary during the rehydration and optimal time to achieve target dehydration goal is reported by Bolaji (2015).

## Primary necessities in Ogi industries

Commercialization of Ogi definitely will require appropriate technology, packaging material and market for the products. The nature of the product may be wet (slurry form) or recently proposed form (powder). The technology may be new or adopted from the technology of corn starch production. The technology and environment can greatly be influenced by the economics of the nations and investors, consumer culture, government policies, provision of necessary amenities and product forms and packaging (Peters and Timmerhaus 1991; World Bank, 1994; Ijaiya and Akanbi, 2009).

## Economic challenges

There is the pressing need to upgrade traditional technologies of food processing and preservation into industrial standard. However, rapid growth and development of small-scale food industries in West Africa could be hindered by implementation of inefficient or inappropriate technologies, poor management, inadequate working capital, limited access to banks and other financial institutions, high interest rates and low profit margins (Fox 1994; Benson 2005).

Small-scale food enterprises which in most cases rely on locally fabricated equipment may lack spare parts for equipment maintenance and repair as a major problem constraining their growth (Fox, 1994; Ijaiya and Akanbi, 2009). The World Bank (1994) established a strong relationship between infrastructures and industrial growth to economy of the nation. Infrastructure is relevant to create platform for viable structures and network to undertake social and economic activities (Ijaiya and Akanbi, 2009; World Bank, 1994). This is generally viewed as the wheel of economy (Ijaiya and Akanbi, 2009; World Bank, 1994; Adeboye, 1989).

This was believed to have positive effect on productive activities, encourage investment, wider movement of goods and people, facilitate information flow and encourages diversified economy (Benson, 2005; Ijaiya and Akanbi, 2009). However, Ijaiya and Akanbi (2009) pointed out a strong negation to this in Nigeria because of the poor deplorable state of most infrastructures. According to Ayodele (1998), about 3000 megawatts (MWs) which was 51% available in 1996 contrary to the expected 5860 MWs installed capacity from thermal (gas and steam) and hydroelectricity, witnessed some decline

subsequently. This has therefore hampered the effective commercialization and mechanization of some traditional technologies.

This among many necessary infrastructures should provide conducive environment for productive activities to take place and facilitate the generation of economic growth (Adeboye, 1989). Ijaiya and Akanbi (2009) stated that efficient infrastructure network can stimulate new investment in other sector (African development Bank (ADB), 1999). The poor provision of infrastructural services and uneven distribution may be a threat to industrialization (;Adeboye 1989;ADB, 1999; Ijaiya and Akanbi, 2009).

### **Standardisation and commercial production of Ogi**

Industrialisation involves comprehensive relationship between workers, employers, equipments, process and society. Industrialisation will necessitate development of new machines, processes and services. These are usually provided for by modern technology (Ijaiya and Akanbi, 2009). Nigeria population is estimated at 168-170 million people out of which about a quarter in the country by estimation consume Ogi for at least once a week (Steinkraus, 1996; Aderiye and Laleye, 2003). The demand in the cities with increasing population is not met because is in a short supply, since most women are engaged in different types of job (Teniola, 1990). Ogi is mostly produced at the household level in majority of the states in the country.

The consumption pattern of some Nigerians fermented product like Ogi and eko was reported by Aderiye and Laleye (2003) among other fermented product popularly consumed in the South West of Nigeria. The variation of the quality attributes of this product subjected to varying processing methods need be addressed. Also, the demands by varieties of consumers will require development. This will necessitate the manipulation of the physical, mechanical, biological and environmental factors such as temperature, moisture content, pH and acidity in increasing the shelf life and optimization of the production process.

Aworh (2008) reported that weaning food like Ogi require sophisticated technology in tuning the process to industrial production of weaning foods. Commercial production of Ogi will result in deliberate and calculated combination of unit operations to improve process. Possible expectation from the industrialisation may contain a continuous or semi continuous processing plant with soaking tank, capable of self draining into a milling section, mechanical sieve, sedimentation tank where it is separated into paste or subsequently processed into dried Ogi powdered based on demand. The food produced is expected to be wholesome, provide good taste, help the house hold economy and provide cultural benefits. Above all, must be appealing to the entrepreneurs. Shelf stability is also important factor in

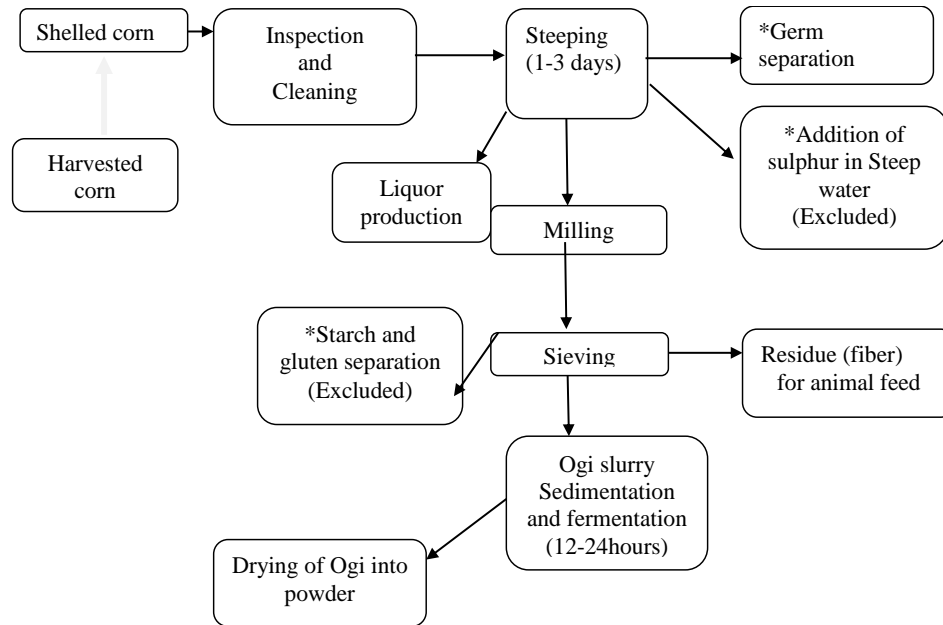
the industrial process. However, the commencement of any industrial process should be after a credible feasibility study. This seems to be apparently missing in the literature. According to Aworh (2008), the traditional methods of food processing and preservation in West Africa remain at the empirical level; this is rather unfortunate. The processes are still very crude, not standardised, and are not based on sound scientific principles (Aworh, 2008). The possibility of large-scale industrial production is discouraging.

Major unit operations of Ogi production involve the steeping, milling, sieving, decanting, sedimentation and packaging depending on the form (wet or dry state) (Akinrele, 1970; Banigo et al., 1974; Akingbala et al., 1981; Banigo and Muller, 1972; Adeniji and Potter, 1978; Sokari, 1992). The first step in preparing the preliminary design of Ogi is likely to establish the bases for designing these specific unit operations. Additionally, simplified flow diagram of the standardised processes and operation must be developed with good understanding of the unit operations. A preliminary material balance may be necessary however subject to subsequent modification and improvement.

The design of Ogi plant is expected to accommodate healthy and safe arrangement of machines, structures, systems or processes to perform desired functions dependent on many physical, economic, cultural and legal factors. This proposed plant must reflect harmonization of the location, plant layout, raw materials and materials for construction, structural design, utilities, buildings, storage, materials handling, safety, waste disposal, federal, state and local laws and patents (Peters and Timmerhaus, 1991). Ogi plant project may definitely involve a wide variety of skills: the researchers, market analysis, design of individual pieces of equipment, cost of estimation, where necessary, consultancy and plant-location surveys. In all of these, the services of engineers and professionals will definitely be required. Estimating the cost of materials and services is however inevitable. This cost estimation should include the total equipment or material cost, installation costs, maintenance costs and replacement costs (Peters and Timmerhaus, 1991).

In the light of the above, a closer look at the technology of corn starch production is well established (Blanchard, 1992; Galitsky et al., 2003; Hohmann and Rendleman, 1993; Johnston and Singh, 2001) and shows similarities with Ogi production: These are soaking or steeping, draining, wet milling and sieving. Drying may be included where necessary for the sake of increasing its shelf life. Corn starch technologies may be an appropriate guide in the design, construction and running of Ogi processing plant as shown in Figure 1.

The modified Ogi production process should exclude de-germing, removal of corn oil and separation of starch and gluten which exist in corn starch production (Figure 1). The cereal is soaked for 24 to 72 h, drained, wet milled and sieved; the Ogi slurry is produced. Collected



**Figure 1.** Flow chart of modification for Ogi production process for corn starch production.

steep-water is often discarded however, may be transformed into liquor as been practiced in the corn starch production while residual collection after sieving can be converted to animal feed. According to Adebolu et al. (2012), antibacterial activity of microorganisms isolated from the liquor of fermented maize Ogi on selected diarrhoeal bacteria show some level of effectiveness.

The cell free extracts of *Lactobacillus brevis* and *Lactobacillus plantarum* from the liquor inhibited the growth of all the test organisms with diameter zone of inhibition ranging from 6.0 - 9.0 mm and 5.0 - 7.0 mm, respectively. This is in support of cooperation of liquor production into commercial production of Ogi

## Conclusion

Many areas have been explored by many researchers with respect to quality, quantity, nutritional, preservation and potential alternative method of production. Ogi's social status is high, because its products are widely consumed virtually in all the 36 states of Nigeria from three predominant cereal: (maize yellow and white, sorghum and guinea corn). The proposed processing plant should be located where the minimum cost of production and distribution can be achieved.

Wet corn milling in starch and corn syrup and Ogi processing share some similarities in unit operation like steeping, draining, milling and sieving or screening. This implies that some of the technologies can be adopted and modified for Ogi processing without new design of entire equipment or plant. However, there must be some

investigation to determine the level of appropriate adoption, modification and application.

The rapid growth and development of small-scale food industries in West Africa should be encouraged by the provision of necessary facilities, industrial policies and environment. Access to low finance will facilitate the translation of traditional process into industrial process.

## Conflict of interests

The author(s) did not declare any conflict of interest.

## REFERENCES

- Achi OK (2005). The potential of upgrading traditional fermented foods through biotechnology. *Afr. J. Biotechnol.* 4(5): 375-380.
- Adebayo CO, Aderiye BI (2010). Antifungal activity of bacteriocins of Lactic acid bacteria from some Nigerian fermented foods. *Res. J. Microbiol.* 5: 1070-1082.
- Adebolu TT, Ihunweze BC, Onifade AK (2012). Antibacterial activity of microorganisms isolated from the liquor of fermented maize Ogi on selected diarrhoeal bacteria. *J. Med. Med. Sci.* 3(6): 371-374.
- Adebolu TT, Olodun AO, Ihunweze BC (2007). Evaluation of Ogi liquor from different grains for antibacterial activities against some common diarrhoeal bacteria in South-West Nigeria. *Afr. J. Biotechnol.* 6 (9): 1140-1143.
- Adejuyitan JA, Abioye AO, Otunola ET, Oyewole YN (2012). An evaluation of some properties of baobab fruit powder and Ogi mixes. *Trans. J. Sci. Technol.* 2: (7): 91-102.
- Adeniji AO, Potter NN (1978). Properties of Ogi powder made from normal, fortified and opaque-2 corn. *J. Food Sci.* 43: 1571-1574.
- Aderiye BI, Laleye SA (2003). Relevance of fermented food products in southwest Nigeria. *Plant Foods Hum. Nutr.* 58: 1-16.
- Adeyemi IA (1983). Dry milling of sorghum for Ogi manufacture. *J. Cereal Sci.* 1: 221-227.



- Adeyemi IA, Beckley O (1986). Effect of period of maize fermentation and souring on chemical properties and amylograph viscosity of Ogi. *J. Cereal Sci.* 4:353-360.
- Adeyemi IA, Soluade EO (1993). Development and quality evaluation of Pawpaw-Ogi. *Plants Foods. Hum. Nutr.* 44 (3): 213 -220.
- Adeyemo SO, Oloyode OB, Odutuga AA (1992). Biochemical analysis of germinating white maize (*Zea mays*) Nig. *J. Nutr. Sci.* 13: 14-18.
- Afolayan MO, Afolayan M, Abua JN (2010). An investigation into sorghum based Ogi (Ogi-Baba) storage characteristics. *Adv. J. Food Sci. Technol.* 2(1):72-78.
- African development Bank (ADB) (1999). Infrastructure development in African Countries, Abijan, Nigeria.
- Agarry OO, Nkama I, Akoma O (2010). Production of Kunun-zaki (A Nigerian fermented cereal beverage) using starter culture. *Int. Res. J. Microbiol.* 1(2): 18-25.
- Ajanaku KO, Oluwole O (2013). Determination of nutritional content of Sorghum-Ogi weaning food mixed with Crayfish (*Paraneopros planifrons*) *Int. J. Chem. Environ. Biol. Sci.* 1 (4):667-669.
- Akanbi CT, Ade-Omowaye BI, Ojo A, Adeyemi IA (2003). Effect of processing factors on rheological properties of Ogi. *Int. J. Food Prop.* 6(3):405-418.
- Akingbala JO, Akinwande BA, Uzo-Peters PI (2005). Effects of color and flavor changes on acceptability of Ogi supplemented with okra seed meals. *Plant Food Hum. Nutr.* 58(3): 1-9.
- Akingbala JO, Onochie EU, Adeyemi IA, Oguntimein GB (1987). Steeping of whole and dry milled maize kernels in Ogi preparation. *J. Food Proc. Preserv.* 11: 1 – 11.
- Akingbala JO, Rooney LW, Faubion JA (1981). A laboratory procedure for the preparation of Ogi, a Nigerian fermented food. *J. Food Sci.* 46: 1523.
- Akinleye OM, Fajolu IO, Fasura AK, Osanyinpeju O, Saboderin AO, Salami OO (2014). Evaluation of microorganisms at different stages of production of Ogi. In: Alimosho Community, Area Southwest, Lagos, Nigeria. *Am. J. Res. Commun.* 2 (10):215-230.
- Akinrele IA (1966). A Biochemical study of the traditional method of preparation of Ogi and its effect on the nutritive value of corn. PhD. Thesis. University of Ibadan, Nigeria.
- Akinrele IA (1970). Fermentation studies on maize during preparation of a traditional African starch- cake food. *J. Sc. Food Agric.* 21:619-625.
- Akinrele IA, Adeyinka O, Edward CC, Olatunji FO, Dina JA, Koleosho OA (1970). The development and production of soy Ogi. Oshodi, Lagos, Nigeria: Federal Institute of Industrial Research (FIRO), Research Report No. 42.
- Akinrele IA, Bassir O (1967). The nutrient value of Ogi, a Nigerian infant food. *J. Trop. Med. Hyg.* 70:279-280.
- Akinrele IA, Edwards CC (1971). An assessment of the nutritive value of maize soy mixture "soy Ogi" as a weaning food in Nigeria. *Brit. J. Nutr.* 26:177-185.
- Akoboundu ENT, Hoskins FM (1987). Potential of corn- cowpea mixture as infant food. *J. Agric.* 1: 111-114.
- Aminigo ER, Akingbala JO (2004). Nutritive composition of Ogi fortified with okra seed meal. *J. Appl. Sci. Environ. Mgt.* 8(2):23-28.
- Aremu MO, Olaofe O, Audu SS, Ijalana DM (2011). Biochemical evaluation of fermented white maize (*Zea Mays* L.) blended with Scarlet Runner Bean (*Phaseolus coccineus* L.) Flour. *The Open Nutraceut. J.* 4:163-171.
- Aworh OC (2008). The Role of Traditional Food Processing Technologies. In: National Development: the West African Experience. *Inter. Union of Food Sci. Technol.* 1-18
- Ayodele AS (1998). Energy crisis in Nigeria: The case of the electric energy market. *Central Bank of Nigeria Bull.* 22(4):19-24.
- Banigo EOI (1969). An investigation into the fermentation and enrichment. University of Leeds, England.
- Banigo EOI, De Man JM, Duitschaever CL (1974). Utilization of high-lysine corn for the manufacture of Ogi using a new, improved processing system. *Cereal Chem.* 51:559-572.
- Banigo EOI, Muller HG (1972a). Manufacture of Ogi (a Nigerian fermented cereal porridge): Comparative evaluation of corn, sorghum and millet. *Can. Inst. Food Sci. Tech. J.* 5: 217-221.
- Banigo, EOI, Muller HG (1972b). Carboxylic acid patten in Ogi in fermentation. *J. Sci. Food Agric.* 23:101-111.
- Benson JO (2005). The dynamics of small business incubation facilities in Fadama areas of Ogun state in Nigeria: a sustainable anti-poverty device. Institute of small business management and entrepreneurship (Isbume). [www.socialedge.org/admin/Attachments/scale/why%20you%20shouldnt%20scale%20up/gcbe1.p\\_1.doc](http://www.socialedge.org/admin/Attachments/scale/why%20you%20shouldnt%20scale%20up/gcbe1.p_1.doc)
- Blanchard PH (1992). Technology of corn wet milling and associated processes. Elsevier, Amsterdam.
- Bolaji OT, (2014). kinetic study of energy reduction and engineering properties of soaked maize grains in the production of "ogi" unpublished PhD. thesis
- Bolaji OT, Akindele AD, Aina OD (2014). Mathematical modeling of drying pattern and thermal properties of Ogi produced from four maize varieties. *Annals Food Sci. Technol.* 15(2):251-258.
- Bolaji OT, Awonorin SO, Olalusi AP, Idowu MA, Henshaw FO, Adepoju PA (2011a). Effect of storage temperature on some Ogi properties. *Adv. J. Food Sci. Technol.* 3(2):89-94.
- Bolaji OT, Awonorin SO, Olalusi PA, Adepoju PA (2011b). Evaluation of changes in pasting properties of Ogi during storage. *Elect. J. Environ. Agric. Food Chem.* 10(1):1865-1872.
- Bolaji OT, Olalusi AP, Adesina BS (2015). Mathematical modeling of drying pattern of Ogi produced from two types of maize grain. *J. Food Res.* 4(1): 174-185.
- Bolaji OT, Oyewo AO, Adepoju PA (2014). Soaking and drying effect on the functional properties of Ogi produce from some selected maize varieties. *Am. J. Food Sci. Technol.* 2(5):150-157.
- Calderon GL, Guyot JP (2003). Fermentation by *Lactobacillus fermentum* Ogi E1 of different combinations of carbohydrates occurring naturally in cereals: Consequences on growth energetic and  $\alpha$ -amylase production. *Int. J. Food Micro.* 80:161-169
- Central Bank of Nigeria (CBN) (1994). Annual Report and statement of account for the year ended 1994, Lagos, Nigeria.
- Central Bank of Nigeria (CBN) (1996). Annual Report and statement of account for the year ended 1996, Lagos, Nigeria.
- Egounlety M, Aworh OC (1991). Production and physiochemical properties of tempeh-fortified maize based weaning foods. In: Sofa SD (Ed.). Proceedings of Seminar on development of the protein energy foods from grain legumes, February 5–7, 1991. University of Lagos, Nigeria.
- Egounlety M, Syarif R (1992). Study on the supplementation of Ogi with Tempeh. *Nigeria Food J.* 10:93-102.
- Ekpenyoung TE, Fatuga BL, Oyenuga VA (1977). Fortification of maize flour based diets with blends of cashew nut meal, African locust bean meal and sesame oil meal. *J. Sci. Food Agric.* 28:710-716.
- Enujiugha VN (2006). Supplementation of Ogi, a maize-based infant weaning food, with African oil bean seed (*Pentaclethra macrophylla* Benth). *Int. J. Postharvest Technol. Innov.* 1 (2):201-211.
- Fasasi OS, Adeyemi IA, Fagbenro OA (2007). Functional and pasting characteristics of fermented maize and Nile Tilapia (*Oreochromis niloticus*) Flour Diet Pakistan *J. Nutri.* 6 (4):304-309.
- Fashakin JB, Ogunsola F (1982). The utilization of local foods in the formulation of weaning foods. *J. Trop. Pediat. Oxford.* 28: 93-96.
- Fox WF (1994). Strategic Options for Urban infrastructure management, UNDP/UNCHS/World Bank Urban Management Program No 6 Central Bank of Nigeria (CBN) 1994.
- Galitsky C, Worrell E, Michael R (2003). Energy efficiency improvement and cost saving opportunities for the corn wet milling industry: An energy star® Guide for Energy and Plant Managers. Sponsored by the U.S. Environmental Protection Agency Ernest Orlando Lawrence Berkeley national laboratory 2-84.
- Hohmann N, Rendleman CM (1993). Emerging technologies in ethanol production. U.S. Department of Agriculture, Economic Research Service. *Agricultural Information Bulletin* No. 663.
- Igbedioh SO, Ogbeni AO, Adole GM (1996). Infant weaning practices of some Tiv women resident in Makurdi, Nigeria. *Nutr Health.* 11(1):13-28.
- Ijaiya GT, Akanbi SB (2009). An empirical analysis of the long-run effect of infrastructure on industrialization in Nigeria. *J. Int. Rev.* 2(1-2):135-149.
- Inyang CU, Idoko CA (2006). Assessment of the quality of Ogi made from malted millet *Afr. J. Biotechnol.* 5 (22):2334-2337.
- Jay, M.J. (2004). *Modern Food Microbiology*. New Delhi: S.K. Jain For CBS Publishers and Distributors.
- Johnston DB, Singh V (2001). Use of proteases to reduce steep time

- and SO<sub>2</sub> requirements in a corn wet-milling process. *Cereal Chem.* 78 (4):405-411.
- Ladunni E, Aworh OC, Oyeyinka SA, Oyeyinka AT (2013). Effects of drying method on selected properties of Ogi (Gruel) prepared from sorghum (*Sorghum vulgare*), Millet (*Pennisetum glaucum*) and Maize (*Zea mays*). *Food Proc. Technol.* 4 (7): 4-7.
- Mensah PP, Tomkins AM, Drasar BS, Harrison TJ (1988). Effect of fermentation of Ghanaian maize dough on the survival and proliferation of 4 strains of *Shigella flexneri*. *Trans Roy. Soc. Trop. Med. Hyg.* 82:635-636.
- Nago MC, Hounhouigan JD, Akissoe N, Zanou E, Mestres C (1998). Characterization of Beninese traditional Ogi, a fermented Sorghum slurry: Physicochemical and microbiological aspects. *Int. J. Food Sci. Technol.* 33: 307-315.
- Nnanyelugo DO, Onofiok, NO (2004). Weaning Foods in West Africa: Nutritional problems and possible solutions. Occasional paper Department of Home Science and Nutrition, University of Nigeria, Nsukka. Retrieved August 2<sup>nd</sup>, 2010, from <http://www.unu.edu/unupress/food/vl91e/ch06.htm>.
- Odufa SA (1985). African Fermented Foods. In: *Microbiology of Fermented Foods*. Vol 2, Wood BJ (ed.). Elsevier Applied Science Publishers. London and New York. pp.155-199.
- Odufa SA, Adeyeye S (1985). Microbiological changes during the traditional production of ogi-baba, a West African fermented sorghum gruel. *J. Cereal Sci.* 3: 173-180.
- Ogunbanwo S, Sanni A, Onilude A (2003b). Influence of cultural conditions on the production of bacteriocin by *Lactobacillus brevis* OG1. *Afr. J. Biotechnol.* 2(7):179-184.
- Ogunbanwo ST, Sanni AI, Onilude AA (2003a). Characterization of bacteriocin produced by *Lactobacillus plantarum* F1 and *Lactobacillus brevis* OG1. *Afr. J. Biotechnol.* 2(8):219-227.
- Ohenhen RE, Ikenemoh MJ (2007). Shelf stability and enzyme activity studies of Ogi: A corn meal fermented product. *J. Amer. Sci.* 3(1): 38-42.
- Ojo A, Akanbi CT (2004). Rheology of Soy-Ogi: Effect of concentration and temperature. *J. Food Eng.* 72(2): 141-146.
- Ojofeitimi EO, Afolabi OA, Fapojuwo OO (1984). The Use of black-eyed cowpea- maize gruel mixture "Ewa- 'ogi'" in the prevention of infantile protein malnutrition. *Nutr. Rep. Intern.* 30(4):841-852.
- Ojokoh AO (2009). A Comparative study on the effect of traditional and improved methods of fermentation in the production of Ogi food oriental. *J.Chem.* 25(3):471-476.
- Okafor N (1981). A scheme for the improvement of fermented foods of Africa, south of the Sahara, In: *Global impacts of Applied Microbiology*. Emejuaiwe SO, Ogunbi O, Sanni SO (Eds.). London: Academic Press. pp. 61-69.
- Okafor N (1983). Processing of Nigerian indigenous fermented foods, a chance for innovation. *Nig. Food J.* 1:32-37.
- Oke OI (1967). Chemical studies on the Nigerian food stuff Ogi. *Food Tech.* 21:202-204.
- Okoli EC, Adeyemi IA (1989). Manufacturing of Ogi from malted (germinated) corn (*Zea mays*): Evaluation of chemical, pasting and sensory properties. *J. Food Sci.* 54:971-973.
- Olanrewaju OO, Victor OO, Titilayo TA (2009). Safety of small-scale food fermentations in developing countries. *Internet J. Food Saf.* 11: 29-34.
- Olasupo NA, Olukoya DK, Odufa SA (1997). Identification of *Lactobacillus* species associated with selected African fermented foods. *J. Biosci.* 51:105-108.
- Olatunji O (1977). Production and utilization of local dry corn milled products in Nigeria. *Nutr. Rep. Int.* 16: 596-601.
- Olukoya DK, Ebugwei S, Olasupo NA, Ogunjinmi A (1994). Production of Dogit: An improved Ogi (Nigerian fermented weaning food) with potentials for use in diarrhea control. *J. Trop. Pediatr.* 40:108-114.
- Oluseyi AK, Oluwafunmilola A, Oluwasegun ST, Abimbola AA, Oluwatoyin AC, Olubusola O (2013). Dietary fortification of Sorghum-Ogi using Crayfish (*Paranephrops planifrons*) as Supplements in infancy. *Food Sci. Qual. Manag.* 15 (Online).15:1-9. [www.iiste.org](http://www.iiste.org).
- Oluwafemi F, Adetunji AF (2011). Antimicrobial activities of lactic acid bacteria isolated from traditionally-fermented maize (Ogi) against *Candida albicans*. *J. Appl. Biosci.* 41:2820-2835.
- Oluwamukomi MO, Eleyinmi AF, Enujigba VN (2005). Effect of soy supplementation and its stage of inclusion on the quality of Ogi - a fermented maize meal. *Food Chem.* 91(4):651-657.
- Omemu AM, Adeosun OF (2010). Evaluation of hazards and critical control points of Ogi in small scale processing centers in Abeokuta. *Nigeria J. Appl. Biosci.* 29:1766-1773.
- Omemu AM, Oyewole OB, Bankole MO (2007). Significance of yeasts in the fermentation of maize for Ogi production. *Food Microbiol.* 24: 571-576.
- Onwuakor CE, Nwaugo VO, Nnadi CJ, Emetole JM (2014). Effect of varied culture conditions on bacteriocin production of four *Lactobacillus* species isolated from locally fermented maize (Ogi). *Glob. J. Med. Res. Microb. Pathol.* 14 (4): 10-16
- Onyekwere OO, Akinrele IA (1977). Ogi, a Nigerian fermented maize beverage. In: *Symposium on Indigenous Fermented Foods*, Bangkok, Thailand.
- Onyekwere OO, Akinrele IA, Koleoso OA (1989). Industrialization of Ogi. In: Steinkraus KH (Ed.). *Industrialization of Indigenous Fermented Foods*. Marcel Dekker, New York, pp. 329-360.
- Onyekwere OO, Akinyele IA, Koleoso OA (1989). Industrialization of Ogi fermentation. *Industrial. Indig. Fermented Foods.* 33: 329-362.
- Osungbaro TO (1990a). Effect of differences in varieties and dry milling of maize on the textural characteristics of Ogi (fermented maize porridge) and Agidi (fermented maize meal). *J. Sci. Food Agric.* 52: 1-12.
- Osungbaro TO (2009). Physical and nutritive properties of fermented cereal foods. *Afr. J. Food Sci.* 3(2): 023-027.
- Otunola ET, Apoeso O, Adeyemi IA (1998). Development and Evaluation of Maize-Tempeh mixes as an instant food product. *Biosci. Res. Commun.* 10(4):311-316.
- Otunola ET, Ogunsoola O, Abioye VF (2006). Effect of Tempeh on some properties of 'Agidi', a West African Fermented Maize Gel. *Int. J. Food Agric. Res.* 3(1):119-128.
- Oyewole OA, Isah P (2012). Locally Fermented Foods in Nigeria and their Significance to National Economy: a Review. *J. Recent Adv. Agric.* 1(4):92-102
- Peters MS, and Timmerhaus KD, (1991) plant design and economics for chemical engineers fourth edition McGraw-Hill, Inc. pp. 13-80.
- Sanni AI, Asiedu M, Ayernor GS (2001). Influence of processing conditions on the nutritive value of Ogi-Baba, a Nigerian fermented sorghum gruel. *Plant Food Hum. Nutr.* 56(3):217-223.
- Sokari TG (1992). Improving the nutritional quality of Ogi and Gari. *Applications of biotechnology to traditional fermented foods*. National Academic Press. p. 93.
- Steinkraus KH (1996). Indigenous fermented food involving an acid fermentation. *Handbook of Indigenous Fermented Foods*. Marcel Dekker, Inc. New York.
- Teniola OD (1990). Development of starter culture for the production and nutritional improvement of Ogi. PhD. Thesis. Botany and Microbiology Dept., University of Ibadan, Nigeria.
- Teniola OD, Odufa SA (2001). The effects of processing methods on the level of lysine, methionine and the general acceptability of Ogi processed using starter cultures. *Int. J. Food Microbiol.* 63:1-9.
- Teniola OD, Odufa SA (2002). Microbial assessment and quality evaluation of ogi during spoilage. *World J. Microbiol. Technol.* 18: 731-737.
- Wakil SM, Daodu AA (2011). Physiological properties of a microbial community in spontaneous fermentation of maize (*Zea mays*) for Ogi production. *Int. Res. J. Microbiol.* 2(3):109-115.
- World Bank (1994). *Infrastructural for development*. World Development Report 1994, New York.

## Full Length Research Paper

# The impact of processing on the nutritional, mineral and vitamin composition of palm kernel nut (*Elaeis guineensis*)

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Proximate, vitamin and mineral compositions of palm kernel nut (*Elaeis guineensis*) in the raw and processed form was investigated using standard analytical methods. The proximate composition (g/100g) for the raw palm kernel nut was as follows: moisture  $7.15 \pm 0.21$ , dry matter  $92.86 \pm 0.21$ , ash  $2.90 \pm 0.00$ , crude fibre  $11.38 \pm 0.04$ , ether extract  $52.40 \pm 3.11$ , crude protein  $8.69 \pm 0.01$  and carbohydrate  $19.59 \pm 0.00$ . The mineral composition (mg/100 g) revealed for calcium  $21.47 \pm 0.01$ , magnesium  $28.29 \pm 0.54$ , sodium  $37.80 \pm 0.07$ , potassium  $20.30 \pm 0.023$ , phosphorus  $5.78 \pm 0.02$  and iron  $1.14 \pm 0.08$ . The vitamin composition (mg/100 g) was as follows: vitamin B<sub>1</sub>  $0.09 \pm 0.01$ , vitamin B<sub>2</sub>  $0.05 \pm 0.01$ , vitamin C  $1.51 \pm 0.01$ , vitamin E  $6.16 \pm 0.23$  and vitamin A  $2.49 \pm 0.00$ . For the processed palm kernel nut had the following from the proximate composition (g /100 g): moisture  $6.35 \pm 0.078$ , dry matter  $93.66 \pm 0.078$ , ash  $2.87 \pm 0.035$ , crude fibre  $11.32 \pm 0.120$ , ether extract  $49.56 \pm 0.057$ , crude protein  $8.58 \pm 0.177$  and carbohydrate  $21.34 \pm 0.40$ . Results show that processing has little effect on the nutritional contents of palm kernel nuts. The vitamin composition was affected by processing; while the proximate and mineral compositions were not significantly altered. Palm kernel nuts may thus be consumed in any forms preferred by an individual except for patients deficient in certain vitamins. The nuts are good sources of energy and trace elements.

**Key words:** Palm (*Elaeis guineensis*) kernel, nutrient composition, mineral, vitamin.

## INTRODUCTION

Edible nuts are cultivated and grown in a number of growing conditions and climates, and are valued for their sensory, nutritional, and health attributes. Nuts also contain significant amounts of squalene and tocopherols. Squalene has important beneficial effects on health and tocopherols are powerful antioxidants, which in high doses may reduce the risk of coronary heart disease

(CHD) (Ryan et al., 2006). Nuts are nutritious and are abundant in Nigeria and Africa for example, Nigerian walnut (*Tetracarpidium conophorum*), palm kernel nut (*Elaeis guineensis*) and cashew nut (*Anacardium occidentale*).

Due to high cost of food substances or unavailability of food substances containing the essential classes of food

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and other needed nutrients, there is need to diversify our source of nutrients using nuts. Nuts form a major part of the diet of Nigerians consumed as a meal as well as ingredients of local soups. Several nuts are eaten as snacks such as cashew nuts, palm kernel nuts and walnuts.

Palm kernel (*Elaeis guineensis*) is a specie of palm commonly called African oil palm or macaw fat and is the principal source of palm oil. It is native to West and Southwest Africa, specifically the area between Angola and the Gambia. Oil palm is a species of particular economic importance as it provides one of the most important sources of edible oil for use in a wide range of edible products (Nakkaew et al., 2008). Besides its use in food and feed, palm oil is also one of the most cost-effective feedstock for biodiesel (Lim and Teong, 2010).

The nut is the edible seed of the oil palm tree which is gotten when a palm kernel's hard shell is broken. The palm tree belongs to the *Arecaceae* family, in the order of *Arecales* (Corley and Tinker, 2003). Palm kernel nut are commonly planted in four tropical regions, Africa, Southeast Asia, Latin America and South Pacific (Atasi and Akinhanmi, 2009). The main objective of the palm industries is to generate oil from palm kernel nut. Palm kernel cake from the nuts of palm fruits are generated as by-products along with oil as a main product. Palm kernel meal (PKM) is found in large quantities in a number of tropical countries and is available at competitive prices. Four million metric tonnes of palm kernel cake were produced in the world in 2002 with annual growth of 15% of PKM within the last two decades (FAO, 2002). Palm kernel meal has been widely used in ruminant feed, pigs and rabbit diets. However, some anti-nutritional components such as mannan, galactomannan, xylan and arabinoxylan have been reported to be present in the nut (Atasi and Akinhanmi, 2009), as a result, efforts have been made to improve Palm Kernel Meal (PKM) through supplementation with biotin (Oloyo, 1991), NaOH (Nwokolo et al., 1976) and enzymes (Dingle, 1995). Palm kernel is also a good source of potassium (Ekpa, 1995). The oil from palm nut contains organic food substances and inorganic elements upon which life and industries depend. The fruit yields two oils, palm oil and kernel oil each exhibiting differences in composition, properties and applications. Palm kernel oil is similar to coconut in composition and both are the only sources of lauric oil available in the world market (Berger et al., 1991). Almost 90% of the world's palm oil is used for edible purposes (Sambanthamurthi et al., 2000). Palm kernel oil has also been reported to be rich in important food properties compared to some other oil seeds and nuts as well as a good source of amino acids for children and adults (Atasi and Akinhanmi, 2009). These oils are used industrially and medicinally as antidotes for poisoning and as surface protectants for minor wounds (Ekpa, 1995). Little information is however available on the impact of processing on the nutritive composition of palm kernel

nuts.

Palm kernel nuts constitute a major component of the diet of many Nigerians especially in the rural areas; some people take it raw while others prefer to boil it before consuming. Also, these nuts are very useful in formulating feed for poultry (Ao et al., 2011). It is therefore very important to investigate the level of nutrient in these nuts and the best form in which they can be consumed. Owing to ignorance and lack of manpower especially in the rural areas as a result of migration of most youth to the urban towns, many Nigerians especially those in the urban areas have neglected these natural and wholesome foods, resorting to more processed, less nutritive and more toxic foods adulterated with synthetic vitamins, minerals and preservatives. It is high time therefore, that we returned to basis by consuming more natural and wholesome foods for better nutrition and good health in general.

The aim of this study was to investigate and evaluate the nutrient composition of palm kernel nut and the effect of processing on these nutrients. To evaluate the proximate, mineral and vitamins composition of palm kernel nut in order to ascertain its possible usefulness as food.

## MATERIALS AND METHODS

### Materials

Palm-kernel nuts were collected from Aku village in Igboetiti L.G.A of Enugu state, Nigeria. The nuts were thoroughly screened to remove the bad ones and stones. The nuts were thereafter divided into two groups, one group was cracked releasing the kernel which was then ground into powder. The second group was boiled for 45 min, after it had cooled, it was cut open to release the nuts which were also ground and sun dried for two days. The samples were stored in tightly screwed glass bottles at -20°C until used for analyses.

### Methods of analyses

#### Proximate composition

Moisture, ether extract (crude fat), crude protein (%N × 6.25), ash and crude fibre contents of the samples were determined in accordance with the standard methods of AOAC (1999). Carbohydrate content was estimated by the NFE method described by James (1995). Data were expressed as percentage of dry weight (DW).

#### Mineral analysis

The levels of Ca, Mg, Na, K, P (Macro-element) and Fe (Micro-element) in the raw and processed palm kernel nuts were quantified by procedure of James (1995). The sample for the determination of the element was subjected to acid digestion using concentrated perchloric acid and hydrochloric acid and subsequently the different elements were determined using appropriate methods as described by James (1995). Calcium and magnesium content of the sample was determined by complexometric titration. Sodium and potassium

**Table 1.** Proximate composition of the raw and the processed palm kernel nut.

Constituents (% dry weight)	Palm kernel nut	
	Raw	Processed
Moisture	7.15 ± 0.21 <sup>e</sup>	6.35 ± 0.078 <sup>e</sup>
Dry matter	92.86 ± 0.21 <sup>b</sup>	93.66 ± 0.078 <sup>a</sup>
Ash	2.90 ± 0.00 <sup>d</sup>	2.87 ± 0.035 <sup>d</sup>
Crude fibre	11.38 ± 0.04 <sup>a</sup>	11.32 ± 0.120 <sup>a</sup>
Ether extract (crude fat)	52.40 ± 3.11 <sup>a</sup>	49.56 ± 0.057 <sup>a</sup>
Crude protein	8.69 ± 0.01 <sup>e</sup>	8.58 ± 0.177 <sup>e</sup>
Carbohydrate	19.59 ± 0.00 <sup>a</sup>	21.34 ± 0.40 <sup>a</sup>

Means in same row followed by different letters are significantly different ( $p < 0.05$ ).

were determined by flame photometry method. The phosphorus in the sample was determined by the rando-molybdate (yellow) spectrometry described by James (1995). The mineral concentration was expressed as mg/100 g of dry weight.

#### Vitamin content

The spectrophotometric method by Onwuka (2005) was employed in the determination of vitamin content. Vitamin C content of the sample was determined by the Barakat titrimetric method (Barakat et al., 1973). Vitamin content was expressed as mg/100 g dry weight.

#### Statistical analysis

All the measurements were replicated three times and the data are presented as mean ± SD. The obtained data were subjected to analysis of variance (ANOVA) accompanied with Duncan test using SPSS software (version 16.0 for Windows, SPSS Inc., Chicago) to identify the significance ( $p < 0.05$ ) between means of treatments.

## RESULTS AND DISCUSSION

Results of proximate composition carried out on both the raw and processed palm kernel nuts showed that there were no significant differences between the raw and processed forms of the palm kernel nut (Table 1). Apart from the dry matter content which increased significantly on the processed kernel nut, but all other parameters tested showed no significant difference. The result of the proximate composition is similar to the study of Atasié and Akinhanmi (2009), especially the crude fibre content (11.09%). The fibre content of palm kernel is responsible for the grittiness and poor digestibility of palm kernel cake (Onuora and King, 1985; Alimon, 2004). The crude protein was slightly lower than that reported by Ramin et al. (2010) and Ibrahim (2013) which reported between 10.0 - 19.8%. The slight variation in the other parameters may be due to environmental factors, age and methodology used. Palm kernel cake have been reported to vary considerably in chemical composition (protein, fibre or lipids) depending on the sources (Rhule1996) and

**Table 2.** Mineral content of the raw and the processed palm kernel nut.

Constituents (mg/100g dry weight)	Palm kernel nut	
	Raw	Processed
<b>Macro-elements</b>		
Calcium	21.47±0.01 <sup>d</sup>	21.46 ±0.042 <sup>d</sup>
Magnesium	28.29 ±0.54 <sup>e</sup>	28.68±0.113 <sup>e</sup>
Sodium	37.80±0.07 <sup>a</sup>	37.82±0.028 <sup>a</sup>
Potassium	20.3 ±20.3 <sup>e</sup>	21.82±0.028 <sup>e</sup>
Phosphorus	5.78 ±0.02 <sup>e</sup>	5.78±0.028 <sup>e</sup>
<b>Micro-element</b>		
Iron	1.14 ±0.08 <sup>d</sup>	1.09±0.021 <sup>e</sup>

Means in same row followed by different letters are significantly different ( $p < 0.05$ ).

methodology of oil removal, the proportion of endocarp remaining (Adesehimwe, 2007) and the efficiency of oil extraction from the kernel (Onwudike, 1986; Onuh et al., 2010).

The proximate composition also agrees with report from Sharmila et al. (2014) especially for crude protein, ash and moisture content, however the crude protein was lower than that earlier reported by Ezieshi et al. (2007), while the crude fibre and oil content was within the range. For the minerals, there was no significant difference in the mineral composition of both samples except for Iron (micro-element) which reduced significantly on processing (Table 2). From the result palm kernel nut is a good source of minerals. Our findings agree with the report of Tan et al. (2013) which reported that palm kernels are rich in potassium, phosphorus, calcium, magnesium and manganese (macro-elements) and are therefore recommended for use in the preparation of diets for individuals who are deficient in these elements. Our results also revealed lower iron levels and higher magnesium levels than was reported by Atasié and Akinhanmi (2009).

However for the vitamins, there was significant decrease in vitamins B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub> and E (Table 3). Vitamin B<sub>1</sub> is a co enzyme in decarboxylation reactions of carbohydrate metabolism and a deficiency of it causes Beri-Beri. Vitamin B<sub>2</sub> and B<sub>3</sub> have the same function with other B complex vitamins that is they are constituted of co-enzymes FAD and FMN which are important in metabolic reactions. (AOAC, 1999). This means that processing of palm kernel nut before consumption may affect the rate and efficiency of metabolism in the body negatively when compared to the unprocessed nut.

From the results obtained from this study, while palm kernel may be consumed in the raw or processed forms, individuals who are anemic or prone to anemia may prefer to take it raw since processing reduced the level of iron significantly. Iron is important for the transport of

**Table 3.** Composition of vitamins in the raw and the processed palm kernel nut.

Vitamins (mg/100 g dry weight)	Palm kernel nut	
	Raw	Processed
B <sub>1</sub>	0.09 ± 0.01 <sup>a</sup>	0.05 ± 0.000 <sup>b</sup>
B <sub>2</sub>	0.05 ± 0.01 <sup>b</sup>	0.03 ± 0.007 <sup>c</sup>
B <sub>3</sub>	0.07 ± 0.01 <sup>c</sup>	0.04 ± 0.000 <sup>d</sup>
C	1.51 ± 0.01 <sup>e</sup>	1.65 ± 0.042 <sup>e</sup>
E	6.16 ± 0.23 <sup>c</sup>	4.48 ± 0.170 <sup>e</sup>
A	2.49 ± 0.00 <sup>e</sup>	2.46 ± 0.000 <sup>e</sup>

Means in same row followed by different letters are significantly different ( $p < 0.05$ ).

oxygen by haemoglobin in the body. Its' deficiency leads to Iron anemia. Iron is also involved in energy producing reactions (Anderson and Fitzgerald, 2010). While processing may have some impact on the vitamin composition of palm kernel, it seems to have little or no effect on the proximate and mineral composition as could be seen from the results. While it may be nutritionally relevant as food for human and animals as a result of its wealth of nutrients whether processed or not.

## Conclusions

The present study shows that, the processing has little effect on the nutritional contents of palm kernel nuts. The vitamin composition was affected by processing; while the proximate and mineral compositions were not significantly altered. The authors recommend that individuals who are deficient in some vitamins such as; B<sub>1</sub>, B<sub>2</sub>, B<sub>3</sub> and E consume it only in the unprocessed form for maximum nutrient benefit and efficiency.

## Conflict of interests

The authors did not declare any conflict of interest.

## REFERENCES

- Adesehimwe AOK (2007). Utilization of palm kernel cake as a replacement for maize in diets of growing pigs: Effects on performance, serum metabolites, nutrient digestibility and cost of feed conversion. *Bulg. J. Agri. Sci.* 13: 593-600.
- Alimon AR (2004). The nutritive value of palm kernel cake for animal feed. *Palm Oil Dev.* 40:12-16.
- Anderson J, Fitzgerald C (2010). Iron: An essential Nutrient. Colorado State University Extension. A division of the office of Engagement. No. 9:356.
- Ao X, Zhou TX, Meng QW, Lee JH, Jang HD, Cho JH, Kim IH (2011). Effects of a carbohydrates cocktail supplementation on the growth performance, nutrient digestibility, blood profiles, and meat quality in finishing pigs fed palm kernel meal. *Livest. Sci.* 137:238-243.
- AOAC (1999). Official Method of Analysis. 16<sup>th</sup> ed., Washington, DC: Association of Official Analytical Chemists. pp. 930-935.
- Atasie VN, Akinhanmi TF (2009). Extraction, compositional studies and physico-chemical characteristics of palm kernel oil. *Pak. J. Nutr.* 8:800-803.
- Barakat MZ, Shehab SK, Darwish E, El-Zoherry A (1973). A new titrimetric method for the determination of vitamin C. *Anal. Biochem.* 53(1):245-251.
- Berger KG, Andaner WT, Applewhite TH (1991). The lauric oils medium chain fatty acids source Champaign, IL, American Oil Chemists Society.
- Corley RH, Tinker PB (2003). The oil palm (4<sup>th</sup> ed.). Oxford: Blackwell Science Ltd.
- Dingle JG (1995). The use of enzymes for better performance of poultry. In: Queensland Poultry Science Symposium. The University of Queensland, Gatton.
- Ekpa OD (1995). Bio-inorganic constituents and possible uses of the female inflorescence of the oil palm. *West Afr. J. Biol. Appl. Chem.* 40:13-18.
- Ezieshi VE, Olomu JM (2007). Nutritional evaluation of palm kernel meal types: 1. proximate composition and metabolizable energy values. *Afr. J. Biotechnol.* 6(21):2484-2486.
- FAO(2002). FAOSTAT agriculture data. <http://Faostat.fao.org/default.aspx>. [http://en.m.wikipedia.org/wiki/Elaeis guineensis](http://en.m.wikipedia.org/wiki/Elaeis_guineensis).
- Ibrahim NA (2013). Characteristics of Malaysian palm kernel and its products. *J. Oil Palm Res.* 25(2):245-252.
- James CS (1995). Nut consumption and body weight. *Am. J. Clin. Nutr.* 78 (Suppl.):647S-650S.
- Lim S, Teong LK (2010). Recent trends, opportunities and challenges of biodiesel in Malaysia: An overview. *Renew. Sustain. Energy Rev.* 14(3):938-954.
- Nakkaew A, Chotigeat W, Eksomtramage T, Phongdara A (2008). Cloning and expression of a plastid-encoded subunit, beta-carboxyltransferase gene (accD) and a nuclear-encoded subunit. Biotin carboxylase of acetyl-CoA carboxylase from oil palm (*Elaeis guineensis* Jacq.). *Plant Sci.* 175:497-504.
- Nwokolo EN, Bragg DB, Kitts WD (1976). The availability of amino acids from palm kernel, soybean, cottonseed and rapeseed meal for the growing chick. *Poult. Sci.* 55(6):2300-2304.
- Oloyo RA (1991). Responses of broilers fed guinea corn palm kernel meal based ration to supplemental biotin. *J. Sci. Food Agric.* 55: 539-550.
- Onuh SO, Ortsgera DD, Okoh JJ (2010). Response of broilers chickens to palm kernel cake and maize offal mixed in different ratios. *Pak. J. Oil Palm. Res.* 25(2):245-252.
- Onuora JO, King RD (1985). Technical note preliminary study of Enzymic solubilisation of nitrogenous constituents of palm kernel cake. *Food Chem.* 17:297-302.
- Onwudike OC (1986). Palm kernel as a feed for Poultry: Diets containing Palm kernel meal for starter and grower pullets. *Anim. Feed Sci. Technol.* 16:187-194.
- Onwuka GI (2005). Food Analysis and Instrumentation. Surulere, Lagos. p. 143.
- Ramin M, Alimon AR, Iran M (2010). Effects of fungal treatment on the *In Vitro* digestion of palm kernel cake. *Livest. Res. Rural Dev.* 22: 82.
- Rhule SWA (1996). Growth rate and carcass characteristics of pigs fed on diets containing palm kernel cake. *Anim. Feed Sci. Technol.* 61:167-172.
- Ryan E, Galvin K, O'Connor TP, Maguire AR, O'Brien NM (2006). Fatty acid profile, squalene and phytosterol content of Brazil pecan, pine, pistachio and cashew nuts. *Int. J. Food Sci. Nutr.* 57:219-228.
- Sambanthamurthi R, Sundram K, Tan YA (2000). Chemistry and biochemistry of palm oil. *Prog. Lipid Res.* 39(6):507-558.
- Sharmila A, Alimon AR, Azhar K, NoorHM, Samsudin AA (2014). Improving Nutritional Values of Palm Kernel Cake (PKC) as Poultry Feeds: A Review. *Mal. J. Anim. Sci.* 17(1):1-18.
- Tan YN, Mathews KR, Di R, Ayob MK (2013). Comparative antibacterial mode of action of purified alcalase- and tryptic-hydrolyzed palm kernel cake proteins on the food-borne pathogen *Bacillus cereus*. *Food Control* 3(1):53-58.

Full Length Research Paper

## Enhanced L-citrulline in parboiled paddy rice with watermelon (*Citrullus lanatus*) juice for preventing Sarcopenia: A preliminary study

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**Aging related muscle loss and sarcopenia are public health problems. The objective of this study was to investigate the potential of rice parboiled with watermelon juice as a source of L-citrulline and as a means of slowing or preventing sarcopenia. In the western and industrialized countries, preventive and curative treatments for sarcopenia include physical exercise, pharmacological approach and dietary supplementation. Currently, L-citrulline supplementation plays a central role against decreasing muscle mass and may contribute in sarcopenia protection in the elderly. However, in developing countries, preventive and curative approaches are constrained by poverty and poor access to pharmaceutical supplements. Paddy rice was soaked in watermelon juice at temperatures of 80°C and steamed for 18 h. Rice was then hulled, dried and used to determine L-citrulline and L-arginine contents by HPLC. L-citrulline content increased to 46.6 mg/100 g (on dry basis) and L-arginine content increased to 17.7 mg/100 g (on dry basis) when rice was soaked with watermelon juice. This study shows that parboiled rice with watermelon juice could be a source of L-citrulline and L-arginine, as a means of slowing or preventing sarcopenia for elderly people where access to medical care and pharmaceutical supplements is poor.**

**Key words:** Parboiled rice, watermelon, L-citrulline, sarcopenia, L-arginine.

### INTRODUCTION

Sarcopenia is a pathology characterized by a decrease in muscle mass, strength and function that imparts frailty to the elderly. This condition is generally caused by a low

protein intake or protein metabolism alteration and reduced physical activity (Cruz-Jentoft et al., 2010; Rolland et al., 2009). Sarcopenia is thought to be a complex multifactorial



process facilitated by a combination of factors including the adoption of a more sedentary life style and a less than optimal diet (Boirie, 2009; Paddon-Jones et al., 2008). Various studies estimate that 25% of people over 70 years old and 40% of those over 80 years would be sarcopenic. Preventive or curative measures must be maintained during the whole life of the affected person. As such, sarcopenia and weight loss are a major public health challenge around the world (Renoud et al., 2014).

In western and industrialized countries, physical exercise, hormones and drugs therapy approaches have been proposed as mechanisms for treatment of sarcopenia (Iolascon et al., 2014; Beas-Jiménez et al., 2011; Yarasheski et al., 1999). Currently, no pharmacological protocols have been consensually validated in the prevention of sarcopenia and no pharmaceutical treatment is available (Kishida et al., 2015; Beas-Jiménez et al., 2011). Although, physical activity has well documented benefits in many older populations, the ability to exercise can become compromised by physical disability or disease (Paddon-Jones et al., 2008). It has been shown that an adequate protein intake is necessary for the elderly to benefit from resistance exercise, because protein consumption is the major nutritional determinant for protein synthesis activation due to increased blood amounts of amino acids (hyperaminoacidemia) derived from the proteic digestion of foods (Beas-Jiménez et al., 2011). Treatment of sarcopenia with anabolic hormones has many side effects (Sakuma and Yamaguchi, 2013). The success of postprandial aminoacidemia depends on the ability of the intestine and the liver to retain amino acids from protein digestion. While some amino acids are retained by the splanchnic tissue, splanchnic sequestration is accentuated with age and reduces the availability of amino acids for muscle biosynthesis (Jahan-Mihan et al., 2011; Fouillet et al., 2003).

Promoting muscle anabolism with a protein rich food has several advantages over supplementation. Many plant and animal based protein containing foods are readily accessible and relatively inexpensive, whereas supplements such as essential amino acids frequently are not (Paddon-Jones et al., 2008). One alternative to slow or prevent muscle protein catabolism is the therapeutic use of L-citrulline. Unlike other amino acids, L-citrulline possesses a highly specific metabolism that bypasses splanchnic (internal organ) extraction. Because L-citrulline is not used by the intestine or taken up by the liver, it is made available throughout the body rapidly after ingestion and thus may act directly (Bahri et al., 2013). L-citrulline is a non protein amino acid that is produced predominantly in the intestines (Betue et al., 2013) and metabolized to L-arginine in the vascular

endothelium, renal and other cells. L-arginine is a semi-essential amino acid and participates as an intermediary compound in the urea cycle and is a precursor for endogenous synthesis of nitric oxide due to the activity of nitric oxide synthase, which releases L-citrulline as a byproduct (Wu et al., 2009). L-citrulline increases the blood concentration of L-arginine more effectively than oral L-arginine, as L-citrulline undergoes neither intestinal nor hepatic metabolism, is not a substrate for arginase, and does not induce the expression or activity of the enzyme (Orozco-Gutiérrez et al., 2010). Using L-citrulline to combat sarcopenia has been assessed in clinical trials with promising results (Bahri et al., 2013; Moinard and Cynober, 2007) and plays a key role in the immune system (Yu et al., 1995).

Several pharmacokinetic studies have confirmed that L-citrulline is efficiently absorbed when administered orally (Bahri et al., 2013). Oral L-citrulline supplements, readily available in industrialized countries, could be used to deliver L-arginine to the systemic circulation or as a protein anabolic agent in specific clinical situations for sarcopenia (Bahri et al., 2013). Although L-citrulline represents an interesting nutritional strategy, delivery in the African sub-Saharan countries faces constraints of poverty, poor access to pharmaceutical supplements and lack of adequate medical care.

Watermelon (*Citrullus lanatus*) is a natural and rich source of the non-essential amino acid L-citrulline and is present in watermelon flesh at concentrations ranging from 0.7 to 3.6 g/kg (Collins et al., 2007). L-citrulline has a high bioavailability, with 80% of the ingested amount quickly absorbed in the blood (Mandel et al., 2005).

Watermelon is a common crop grown in West Africa, yet fruit consumption is relatively low because it is not uniformly available and accessible at any time (Layade and Adeoye, 2014). Rice is a staple food for millions of people, including those in Senegal, and there is ongoing research to increase both yield and protein content (Manful, 2010). Parboiling paddy rice is a process developed to improve rice quality by giving higher milling yields and higher nutritional value (Manful et al., 2009; Bleoussi et al., 2009; Sareepuang et al., 2008; Derycke, 2007). It consists of soaking in water, steaming and drying of the paddy rice (Dutta and Mahanta, 2014; Parnsakhorn et al., 2008). Parboiled rice is more nutritious as compared to raw brown rice because the proteins and vitamins are released at the center of the grain after parboiling (Derycke, 2007). Rice parboiled with watermelon offers a means to incorporate L-citrulline and L-arginine into diets as a source of protein to avoid muscle mass wasting.

This study was done to investigate if parboiled rice with watermelon juice could be a source of L-citrulline.

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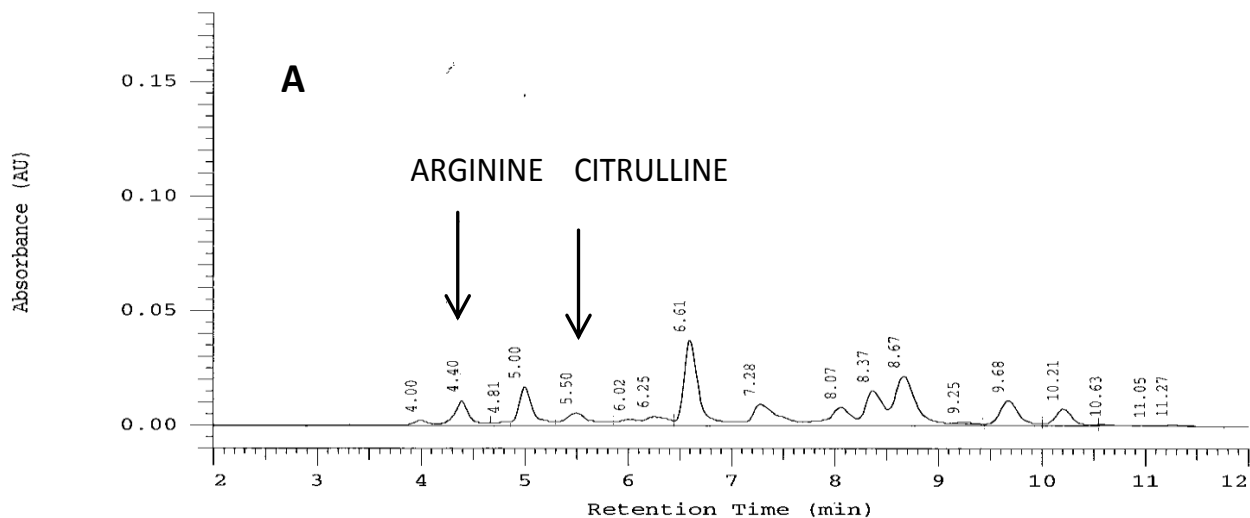


Figure 1. HPLC chromatograms of unparboiled rice.

## MATERIALS AND METHODS

### Plant material

Red-fleshed watermelons were grown from seed in greenhouses and seedlings transplanted one week after germination to the Senegalese Agricultural Research Institute plots in Dakar (Senegal). At maturity, watermelons were harvested and stored in a cold place (at 15°C) for three days. Each watermelon was gently and completely hollowed and all components of the fruit (flesh, peels, juice, and seeds) except rinds were collected. Content of each watermelon was labeled and placed in a polyethylene bag, samples were sealed and packed in another black plastic bag and frozen. After removing from storage, samples were brought to room temperature by holding for one day. Thawed samples were pureed until completely changed into juice.

An irrigated paddy rice 'Sahel 108' newly harvested from the Senegal River Valley was used in this study. Paddy rice harvested too late has a great number of cracked grains and a high percentage of broken rice in the milled product (Bhattacharya, 1969). Paddy rice was first cleaned by winnowing and then washed with water in order to remove impurities (stones, sand and other foreign bodies) and immature seeds. Washing of paddy rice was performed in a basin containing two paddy volumes for three volumes of water. Immature grains that floated to the surface and heavy stones that fell to the bottom by densimetric separation were removed using a sieve. Paddy rice was then drained for a few minutes with a stainless steel drainer. Washed paddy rice was spread on cotton gauze fabric laid on trays as a solar dryer and exposed to the sun until the moisture content was below 13%. After sun drying, rice was kept in bags to prevent contamination.

### Treatments

Treatments were done as outlined in Figure 1. The parboiling process described by Houssou and Amonsou (2005) was followed in our study as the most appropriate to ensure a better quality of parboiled rice. The same steps and procedure described for conventional parboiling paddy rice were followed except the soaking water which was replaced by watermelon juice. The study design consisted of a time/temperature combination where rice

samples were parboiled to a temperature of 80°C then allowed to soak in the water or watermelon juice up to 18 h.

Samples of 3 kg (compared to the average amount of a hulled rice family's daily intake) of paddy rice were soaked (using a butane gas heater) in a pot without a lid and containing water or watermelon juice slightly exceeding the level of rice and was stirred occasionally. Temperature was monitored using a thermometer and once the desired temperature was reached, the operation was stopped, and the pot was removed from the stove. The paddy rice was kept in the covered pot and placed at room temperature (average 27°C) for 18 h, the soaking time programmed to allow cooling overnight and migration of some nutrients inside seeds. Preheating and soaking operations were performed in early afternoon in order to obtain soaking time indicated and start steaming operation, solar drying in the next morning. After 18 h, paddy rice was removed from soaking water and rinsed with fresh clean water and then drained.

### Steaming paddy rice

Steaming was done using a perforated steamer and a pot full of water. Paddy rice was poured into the steamer, covered with a transparent fabric and the whole was placed on the pot. The charged device was warmed up to the appearance of steam followed by the bursting of some paddy grains, for about 25 to 30 min.

### Sun drying of parboiled paddy rice

Parboiled paddy rice was spread again on trays to solar dry (28°C) for two hours, then dried in the shade in a ventilated storage (25°C). This system reduced moisture content of paddy rice below 12% for its conservation and shelling. The steamed paddy rice was then dried at room temperature (25°C). Samples were packed and stored (in a ventilated storage at 25°C).

### Protocol for analysis of L-citrulline and L-arginine using HPLC

All rice samples were dehulled. About 5 g of paddy rice per

**Table 1.** Free amino acid content of L-arginine and L-citrulline (mg/ 100 g dwt) in rice after treatments.

Treatment	L-Arginine	L-Citrulline
Unparboiled	3.27±1.45	0.45±0.31
Parboiled with water	2.50±0.20	0.10±0.28
Parboiled with watermelon	10.51±1.06	21.19±3.20

Data represent averages of three independent repeats ± standard deviation

treatment were gently peeled by hand to ensure the integrity of the grain, and ground using a coffee mill. About 0.1 g of the rice powder was vortexed for 1 min with 1.2 ml 0.03 M H<sub>3</sub>PO<sub>4</sub>, in microfuge tubes, sonicated for 30 min and left at room temperature for 10 min. Samples were centrifuged at 14000 rpm (5417 R, Eppendorf, USA) at 4°C for 20 min. Supernatants were saved and pellet re-extracted with 1.2 ml of 0.03 M H<sub>3</sub>PO<sub>4</sub> as above. Combined supernatants were placed in 5 ml tubes, mixed well and 1 ml of the supernatant was filtered into HPLC vials with a nylon syringe filter (17 mm, 0.2 µm, F2513-2, Thermo Scientific). Vial headspace was washed with N<sub>2</sub>, sealed, and stored at -80°C until run on HPLC.

L-citrulline and L-arginine contents were quantified following the methods of Jayaprakasha et al. (2011). The analyses were made using a HPLC (System-Elite LaChrom, Hitachi, Japan) equipped with a DAD detector set at 195 nm, and autosampler. Sample injections of 10 µl were done on a Gemini 3u C18, 110 A, 250 X 4.6 mm column (Phenomenex, CA, USA) with Security Guard Cartridges (C18 4 x 2.0, Phenomenex) at an oven temperature of 25°C. The mobile phase was 0.015 M H<sub>3</sub>PO<sub>4</sub> with a flow rate of 0.5 ml/min. L-citrulline and L-arginine contents were calculated using standard curves developed with L-citrulline and L-arginine standards (Sigma, USA).

#### Data analysis

All the measurements were replicated three times and the data are presented as mean ± SD.

## RESULTS AND DISCUSSION

L-citrulline and L-arginine contents were increased (21.5 and 10.2 mg/100g dry weight, respectively) in parboiled rice with watermelon juice samples (WmPR) when compared with non-parboiled and traditional parboiled rice (WaPR) (Table 1). The unparboiled rice contained trace amounts of free L-citrulline (0.45 mg/100 g dw) and free L-arginine (3.27 mg/100 g dw). In comparison, rice parboiled with water contained even less of these amino acids (0.10 and 2.50 mg/100 g dw, L-citrulline and L-arginine, respectively). These results suggest that rice parboiled with watermelon juice could be a good food vehicle for L-citrulline intake supplementation. Several studies have found that L-citrulline administration using watermelon puree or juice was associated with increased plasma concentrations of L-citrulline, and metabolically related amino acids such as L-arginine (Moinard et al., 2008; Schwedhelm et al., 2008; Mandel et al.; 2005; Collins et al. 2007).

To our knowledge, this is the first study that helps increase the presence of L-citrulline and L-arginine in rice using parboiling technique with watermelon juice. Tarazona-Diaz et al. (2013) reported that L-citrulline is an excellent candidate to reduce muscle soreness; their study investigated the potential of watermelon juice as a functional drink for athletes. In the same way, consumption of WmPR could bring likely advantages as L-citrulline food vehicle. Rice parboiled with watermelon juice has high levels of L-citrulline and L-arginine that may help alleviate the effects of sarcopenia in the elderly. This assertion requires a further study to determine bioavailability of L-citrulline and frequency of consumption of WmPR which produces beneficial effects.

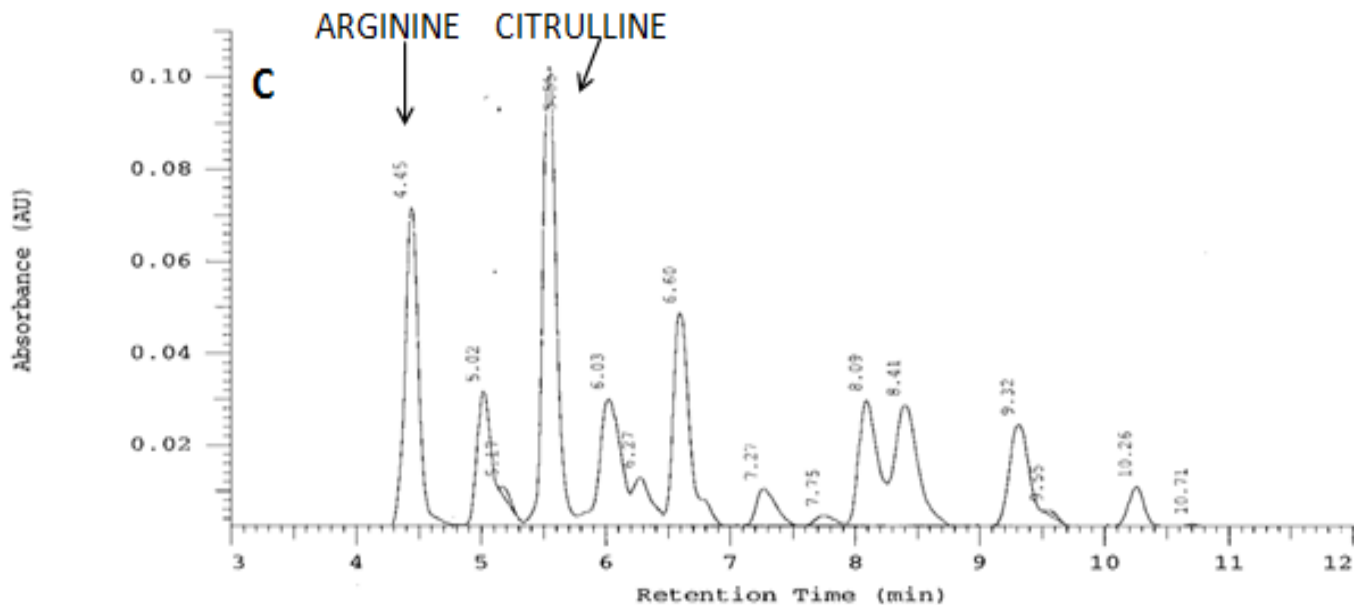
Parboiling rice with watermelon juice process also may be an application to minimize post harvest losses in the African sub-Saharan countries.

Fresh watermelon contains around 4 mg/g of L-citrulline, while the WmPR contained 21 mg/100g dw. Optimizing parboiling parameters should be achieved to establish best performance, and trialing yellow or orange flesh types, which may have more L-citrulline than red-fleshed watermelon (Rimando et al., 2005) should be done.

Dietary requirements for protein and amino acids are characteristics of an individual (WHO/FAO/UNU, 2002). Multiple posologies exist about L-citrulline supplements and some of them are dosed at 250 mg. The present results show that rice parboiled with watermelon juice could contain around 25 mg/100, hence consumption of 350 g WmPR could provide 87.5 mg of L-citrulline and 3 times a daily intake of 350 g WmPR should exceed supplement dose. L-arginine supplementation is also widespread in industrialized countries as compared to Sub-Saharan countries. L-arginine is extensively metabolized by the liver that calls in question of the efficacy of L-arginine supplementation. However, L-citrulline is not captured by the liver and passes freely to the kidneys where it is metabolized into L-arginine (Wijnands et al., 2015). Our method is therefore a good strategy to generate L-arginine and improve the nutritional status of the elderly who do not have access to basic health services.

In this study, results showed that WmPR samples contain more L-arginine than unparboiled or samples parboiled with water (Figures 1 and 2). Furthermore, it has been demonstrated that plasma concentration of L-arginine and L-citrulline are low during illness in children and normalize again after recovery. Plasma L-arginine and L-citrulline are strongly related to the severity of inflammation indicated by plasma CRP concentration (Van Waardenburg et al., 2007). Also, it is necessary to increase consumption level of these amino acids in illness situations. Hence we recommend consumption of rice parboiled with watermelon juice that could be used for undernourished children.

Access to sufficient food with adequate quality to maintain



**Figure 2.** Rice parboiled with watermelon showing HPLC chromatograms with L-citrulline and L-arginine.

normal body composition and function throughout the life-cycle is fundamental to maintaining health. A source of protein is an essential element of a healthy diet (WHO/FAO/UNU, 2002). In consideration of this guidance from WHO and FAO, parboiled rice with watermelon juice may be useful in daily dietary protein intake, managing and preventing specific diseases in addition to its likely positive effects on mechanisms that are involved in the decrease of the muscle mass in humans. According to WHO and FAO, adequate amounts of amino acids of a suitable pattern must be provided in the diet, either in a preformed state, or as appropriate precursors that can be used to generate a suitable mix of amino acids following endogenous transformations, in order to match the demand for protein synthesis and other metabolic pathways.

Parboiling rice with watermelon juice could be considered as a type of food fortification strategy. Fortification is defined as the practice of deliberately increasing the content of an essential micronutrient in a food so as to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health (Allen et al., 2006). Our new technical approach of parboiling using watermelon juice brings nutrients, improves the protein nutritional quality of rice and then could be a food fortification strategy against malnutrition, weight loss and sarcopenia considered as major public health challenge around the world.

However, future research should be focused on the bioavailability of L-citrulline in rice parboiled with watermelon juice due to the fact that protein utilization is generally discussed in terms of digestibility and biological value (WHO/FAO/UNU, 2002).

## Conclusion

Watermelon is a natural source of L-citrulline that bypasses splanchnic sequestration and has a direct effect on muscle protein synthesis, thereby enabling the increase of muscle mass. This work presents the first use of watermelon juice in rice parboiling process. Results suggest that rice parboiled with watermelon juice could be a good food vehicle for L-citrulline and L-arginine. In consequence, an adequate consumption of this food may increase plasma L-citrulline, and a means of slowing or preventing sarcopenia for elderly people in a context of poor access to pharmaceutical supplements.

## Conflict of interests

The author(s) did not declare any conflict of interest.

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## REFERENCES

- Allen L, de Benoist B, Dary O, Hurrell R (2006). Guidelines on food fortification with micronutrients. World Health Organization Food Agricultural Organization of the United Nations. ISBN 92 4 1549401 2.
- Bahri S, Zerrouk N, Aussel C, Moinard C, Crenn P, Curis E, Chaumeil JC, Cynober L, Sfar S (2013). Citrulline: from metabolism to therapeutic use. *Nutrition* 29: 479-484.
- Beas-Jiménez JD de, Lopez-Lluch G, Sanchez-Martinez I, Muro-Jimenez A, Rordiguez-Bies E, Navas P (2011). Sarcopenia: implications of physical exercise in its pathophysiology, prevention and treatment. *RAMD* 4: 158-166.
- Betue CT, De Joosten KFM, Deutz NEP, Deutz A, Vreugdenhil ACE, Van Waardenburg DA (2013). Arginine appearance and nitric oxide synthesis in critically ill infants can be increased with a protein-energy-enriched enteral formula. *Am. J. Clin. Nutr.* 98: 907-916.
- Bhattacharya KR (1969). Breakage of rice during milling and effect of parboiling. *Cereal Chem.* 46: 478-485.
- Bleoussi TM, Roseline, Fofana M, Innocent B, Futakuchi K (2009). Effect of parboiling and storage on grain physical and cooking characteristics of the some NERICA rice varieties. *Second Africa Rice Cong.* 3.3.1-3.3.7.
- Boirie Y (2009). Physio-pathological mechanism of sarcopenia. *J. Nutr. Health Aging* 13(8): 717-723.
- Collins JK, Wu G, Perkins-Veazie P, Spears K, Claypool PL, Baker RA, Clevidence BA (2007). Watermelon consumption increases plasma arginine concentrations in adults. *Nutrition* 23(3): 261-6.
- Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, Topinková E, Van de Woude M, Zamboni M (2010). Sarcopenia: European consensus on definition and diagnosis. Report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 39(4): 412-423.
- Derycke V (2007). Parboiling of rice: changes in starch and protein and their relation to cooking properties. KU Leuven Lab. Food Chem. Biochem. <https://www.biw.kuleuven.be/m2s/clmt/lmcb/publications/docs/vderycke>
- Dutta H, Mahanta CL (2014). Traditional parboiled rice-based products revisited: Current status and future research challenges. *Rice Sci.* 21(4): 187-200.
- Fouillet H, Gaudichon C, Bos C, Mariotti F, Tome D (2003). Contribution of plasma proteins to splanchnic and total anabolic utilization of dietary nitrogen in humans. *Am. J. Physiol.* 285: E88-E97.
- Houssou P, Amonsou E (2005). Development and test of improved parboiling equipment for paddy rice in Bénin. *Bulletin de la Recherche Agronomique du Bénin* Numéro 49.
- Iolascon G, Di Pietro G, Gimigliano F, Mauro GL, Moretti A, Giamattei MT, Ortolani S, Tarantino U, Brandi ML (2014). Physical exercise and sarcopenia in older people: Position paper of the Italian Society of Orthopedics and Medicine (OrtoMed). *Clin. Cases Miner. Bone Metab.* 11(3): 215-221.
- Jahan-Mihan A, Luhovy BL, El Khoury D, Anderson GH (2011). Dietary proteins as determinants of metabolic and physiologic functions of the gastrointestinal tract. *Nutrients* 3(5): 574-603.
- Jayaprakasha GK, Murthy KNC, Patil BS (2011). Rapid HPLC-UV method for quantification of L-citrulline in watermelon and its potential role on smooth muscle relaxation markers. *Food Chem.* 127: 240-248.
- Kishida Y, Kagawaa S, Arimitsua J, Nakanishia M, Sakashitaa N, Otsukaa S, Yoshikawab H, Hagiharaa K (2015). Go-sha-jinki-Gan (GJG), a traditional Japanese herbal medicine, protects against sarcopenia in senescence-accelerated mice. *Phytomedicine* 22(1): 16-22.
- Layade AA, Adeoye IB (2014). Fruit and vegetable consumption among students of tertiary institutions in Oyo State. *RJOAS* 6:30.
- Mandel H, Levy N, Izkovitch S, Korman SH (2005). Elevated plasma citrulline and arginine due to consumption of *Citrullus vulgaris*. *J. Inher. Metab. Dis.* 28:467-472.
- Manful J (2010). Developing rice varieties with high grain quality in Africa: Challenges and prospects. *Africa Rice Center (Africa Rice)*, Second Afr. Rice Cong. 1.20.1-1.20.3. <http://www.africarice.org/workshop/ARC>.
- Manful JT, Abbey LD, Coker RD (2009). Effect of artisanal parboiling methods on milling yield and cooked rice textural characteristics. *J. Food Qual.* 32:725-734.
- Moinard C, Cynober L (2007). Citrulline: A new player in the control of nitrogen homeostasis. *J. Nutr.* 137: 1621S-1625S.
- Moinard C, Nicolis I, Neveux N, Darquy S, Bénazeth S, Cynober L (2008). Dose-ranging effects of citrulline administration on plasma amino acids and hormonal patterns in healthy subjects: The Citrodose pharmacokinetic study. *Br. J. Nutr.* 99: 855-862.
- Orozco-Gutiérrez JJ, Castillo-Martínez L, Orea-Tejeda A, Vázquez-Díaz O, Valdespino-Trejo A, René Narváez-David R, Candace Keirns-Davis C, Olín Carrasco-Ortiz O, Navarro-Navarro A, Sánchez-Santillán R (2010). Effect of L-arginine or L-citrulline oral supplementation on blood pressure and right ventricular function in heart failure patients with preserved ejection fraction. *Cardiol. J.* 17: 612-618.
- Paddon-Jones D, Short KR, Campbell WW, Volpi E, Wolfe RR (2008). Role of dietary protein in the sarcopenia of aging. *Am. J. Clin. Nutr.* 87:1 562S-1566S.
- Parnsakhorn S, Noomhorm A (2008). Changes in physicochemical properties of parboiled brown rice during heat treatment. *Agric. Eng. Int.* 10: 1-20.
- Renoud A, Ecochard, R, Marchand, F, Chapurlat, R, Szulc P (2014). Predictive parameters of accelerated muscle loss in men—MINOS Study. *Am. J. Med.* 127: 554-561.
- Rimando AM, Perkins-Veazie PM (2005). Determination of citrulline in watermelon rind. *J. Chromatogr.* 1078: 196-200.
- Rolland Y, Valerie Lauwers-Cances V, Cristini C, Van Kan GA, Janssen I, Morley JE, Vellas B (2009). Difficulties with physical function associated with obesity, sarcopenia, and sarcopenic-obesity in community-dwelling elderly women: the EPIDOS (EPI Demologie de l'Osteoporose) Study. *Am. J. Clin. Nutr.* 89: 1895-1900.
- Sakuma K, Yamaguchi A (2013). Sarcopenic obesity and endocrinal adaptation with age. *Int. J. Endocrinol.* 204164. <http://www.hindawi.com/journals/ije/2013/204164/>
- Sareepuang K, Siriamornpun S, WisetLMeeso N (2008). Effect of soaking temperature on physical, chemical and cooking properties of parboiled fragrant rice. *World J. Agric. Sci.* 4(4):409-415.
- Schwedhelm E, Maas R, Freese R, Jung D, Lukacs Z, Jambrecina A, Spickler W, Schulze F, Böger RH (2008). Pharmacokinetic and pharmacodynamic properties of oral L-citrulline and L-arginine: impact on nitric oxide metabolism. *Br. J. Clin. Pharmacol.* 65: 51-59.
- Tarazona-Díaz MP, Alacid F, Carrasco M, Martínez I, Aguayo E (2013). Watermelon juice: potential functional drink for sore muscle relief in athletes. *J. Agric. Food Chem.* 61:7522-7528.
- Van Waardenburg DA, Betue, CT de, Luiking YC, Engel M, Deutz NE (2007). Plasma arginine and citrulline concentrations in critically ill children: Strong relation with inflammation. *Am. J. Clin. Nutr.* 86: 1438-1444.
- WHO/FAO/UNU (2002). Protein and amino acid requirements in human nutrition. WHO Technical Report Series 935, 265 p.
- Wijnands KAP, Castermans TMR, Hommen MPJ, Meesters DM, Poeze M (2015). Arginine and Citrulline and the Immune Response in Sepsis. *Nutrients* 7: 1426-1463.
- Wu G, Bazer FW, Davis TA, Kim SW, Li P, Rhoads JM, Satterfield MC, Smith SB, Spencer TE, Yin Y (2009). Arginine metabolism and nutrition in growth, health and disease. *Amino Acids* 37: 153-168.
- Yarasheski KE, Pak-Loduca J, Hasten DL, Obert KA, Brown MB, Sinacore DR (1999). Resistance exercise training increases mixed muscle protein synthesis rate in frail women and men  $\geq$  76 yr old. *Am. J. Physiol.* 277: E118-E125.
- Yu YM, Ryan CM, Burke JF, Tompkins RG, Young VR (1995). Relations among arginine, citrulline, ornithine, and leucine kinetics in adult burn patients. *Am. J. Clin. Nutr.* 62: 960-968.





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