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Sub-Saharan African maize-based foods: Technological perspectives to increase the food and nutrition security impacts of maize breeding programmes

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ABSTRACT

The demand for maize in Sub-Saharan Africa will triple by 2050 due to rapid population growth, while challenges from climate change will threaten agricultural productivity. Most maize breeding programmes have focused on improving agronomic properties and have paid relatively little attention to postharvest qualities, thus missing important opportunities to increase the contribution to food and nutrition security. This paper considers current and potential food uses of maize in Africa and proposes six objectives to enhance the contribution of maize breeding programmes to food and nutrition security: (1) enhance nutrient density; (2) enhance suitability for use in bread and snacks; (3) improve characteristics for consumption as green maize; (4) improve characteristics that enhance the efficiency of local processing; (5) reduce waste by maximising useful product yield and minimising nutrient losses; (6) reduce the anti-nutrient content of grain.

1. Introduction

The growing availability of staple foods in Sub-Saharan Africa (SSA) since the 1990s has substantially reduced the prevalence of undernutrition (Andersson et al., 2017). Staple foods in SSA are characterized by high carbohydrate content, but are low in other food nutrient components like protein, vitamins and minerals (Ranum et al., 2014). One of the major staple crops in SSA is maize, which is consumed in many forms including infant foods, snacks and main dishes. Populations in regions with heavy maize consumption may suffer malnutrition due to natural deficiencies or low quantities of some nutrients in maize, limitations of the maize food matrix, presence of anti-nutrients, physical loss or chemical damage to the nutritional composition during post-harvest handling and limited alignment of maize breeding programmes with preferences of end users, i.e., maize processors and consumers (Ranum et al., 2014). Preferences for maize and maize-based foods differ across Africa, thus implying that general solutions are not feasible for the diverse and dynamic continent (Smale et al., 2013). Research and development (R&D) policies in Africa generally emphasise improving agronomic properties such as yield and tolerance to abiotic and biotic stresses. In contrast, understanding characteristics such as taste, colour, nutritional value and suitability for use in preparing local or novel dishes seldom receives the attention it deserves (Hebinck et al., 2015).

The ultimate measure of the success of maize breeding efforts is the demand and adoption of their new varieties by end users. Breeders develop new varieties based on product profiles, which are a list of traits and characteristics that must be achieved in the new variety for it to succeed. More than one product profile is needed to define the needs of all clients, including processors and consumers. An adequate understanding of the needs of maize users, and integrating this understanding into product profiles targeted by breeding programmes across SSA will help to properly harness research resources, increase adoption of novel maize varieties, improve nutrition and meet the needs of traditional and modern food processes. Between 2010 and 2050 the population of Africa is expected to double, with urbanization levels changing from one third to more than half. Once food security is assured, consumers will increasingly demand quality traits. Maize food uses can be expanded to support the rural/urban transition by offering more nutritious food products and enhancing processing efficiency.

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This is critical because to date various maize varieties with improved agronomic traits are facing challenges along the value chain, such as differences in organoleptic preferences and processing requirements of users, limiting the utilisation of the crop for food (Muzhingi et al., 2008a; Nkhabutlane et al., 2014). Strategies based on maize breeding and improved processing methods that hinge on a critical understanding of users' preferences and nutritional needs could help people meet their daily dietary requirements, and position breeding programmes in developing countries for greater impact.

This paper examines the preferences and needs of maize users in SSA and suggests traits that maize breeding programmes might include in their portfolio to further increase the impact of new varieties on food and nutrition security. The research did not consider the specific needs of each country in SSA; instead, it focused on what is characteristic for two major maize production and consumption regions, i.e. Western and Eastern/Southern Africa, where maize is a staple food. Likewise, the research did not take into account the ease or difficulty of incorporating these traits into new varieties but identified some possible quality trait targets and the current methods for measurement. The review serves as a foundation for further work to meet users' needs and improve maize value chains.

1.1. Categories of maize-based foods

In general, we can distinguish six categories of maize-based foods in Africa, namely: whole-maize foods, wet-ground maize foods, snacks and bread, maize sourdough and dumplings, porridges and beverages. Examples of maize-based foods are summarised in Table 1; a comprehensive list of maize-based foods, their descriptions and frequency of consumption can be found in Ekpa et al. (2018).

1.2. Maize preferences for food in Africa

Flint, dent, pop-maize (popcorn), waxy, sweet and floury maize types of diverse colours, sizes and shapes are commercially grown for human consumption around the world. Grain colour is an important selection criterion for users in Africa, where white is generally preferred over yellow. Although 90% of globally produced maize is yellow, white maize predominates in Africa with over 90% of the total maize crop; it also accounts for more than 30% of global white maize production (Khumalo et al., 2011; Mccann, 2005).

Yellow maize is in increasing demand for animal feed because it gives a deep yellow colouration to egg yolks, poultry skin and animal fat, which consumers attribute to healthiness and freshness (Anthony, 2014; Iken and Amusa, 2004). Human consumption of yellow maize in Africa may continuously decline as animal feed use rises. For instance, in South Africa, the commercial yellow maize area (mostly for feed) is expected to increase by 1.4% per annum while the white maize area decreases by 1.5% per annum (Bfap, 2016; Rosegrant et al., 2001). In a survey conducted by Pillay et al. (2011), some respondents indicated that they only see yellow maize in shops that sell animal feed, not human food; for that reason, it is only for animals. This issue is outside the scope of the current study, which focuses on maize for human food from a food technological and consumer point of view. Information about trends in maize for animal feed in Africa can be found in (Rosegrant et al., 2001; Smale et al., 2013)

The predominance of white maize for food production may be traced to many cultural valuations or social status (prestige) considerations: "white is superior" or "the whiter the better": the influence of indigenous competitive staple crops; government policies; organoleptic differences; a desire for the brightly coloured finished products; and familiarity (i.e. people are used to eating white maize) (Khumalo et al., 2011; Mccann, 2005; Muzhingi et al., 2008b; Pillay et al., 2011; Ranum et al., 2014; White and Johnson, 2003). The association of yellow maize with food aid that was poorly handled or stored during transport and importation, resulting in an unacceptable taste, has been reported to have negatively influenced its acceptance as food (Pillay et al., 2011). The choice of colour could be customarily driven by indigenous competitive or substitute staple crops. For instance, in the eastern region of Nigeria where *gari* (fermented cassava flakes) is commonly prepared with palm oil, which appears yellowish, people prefer yellow maize, e.g. for making *akamu* porridge. In the western part of the country, where finished products made from cassava are white, people prefers white maize, e.g. for making *ogi* porridge.

In Eastern Africa, yellow maize is rarely found in Kenyan markets; only 26% of people would consider buying yellow maize at the same price as white maize (De Groote and Kimenju, 2012). Consumers need an average price discount of 37% in Kenya, 30 − 40% in Mozambique and 10% in Zimbabwe to accept yellow maize instead of white (De Groote and Kimenju, 2012). The perception differs among age groups; preschool children in rural South Africa showed a preference for yellow maize-based over white maize-based food products, while older groups preferred the white maize-based foods (Pillay et al., 2011). The rejection of yellow maize has been attributed to a dislike for the colour and

Table 1
Examples of maize-based foods in Africa.

Food category	Major processing steps	Examples
Whole-grain foods	Cooking, steaming, roasting	Adalu, egbo (Nigeria); githeri, muthokoi (Kenya); aboda (Benin); ayibli, nkyekyerewa, adibabli (Ghana); kandy, makande (Tanzania); mangai, mutakura (Zimbabwe); lusontfwana, tinhlumaya- nemphuphu (Swaziland); setampo (Lesotho); umngqusho, samp (South Africa); corn tchap (Cameroon); roasted & boiled maize (across Africa)
Wet-ground maize foods	Wet grinding, steaming	Amiwo, abla (Benin); sapala, abari (Nigeria); akakla, ofam (Ghana); koga (Cameroon); mohlefe (Lesotho); shamsi, fallahi (Egypt); Maputi (Zimbabwe)
Bread and snacks	Fermentation, baking, frying and roasted	Masa, donkwa (Nigeria); kpome-klekle, tale tale (Benin); dzowee, mamu kaklo (Ghana); injera, dabo (Ethiopia); muufo (Somalia); Monepola oa Poone feela (Lesotho); chigumu (Malawi); Chimodho (Zimbabwe); Popcorn (all over Africa)
Sourdough and dumplings	Soaking, fermentation, steaming and cooking	Ogi, donkunu (Nigeria); amo, kenkey (Ghana); poto-poto, mawe, akassa (Benin); mutwiwa (Zimbabwe); doklu (Côte d'Ivoire); leqebekoane (Lesotho)
Porridges	**Unfermented:** Milling, cooking	Mgaiwa phala (Malawi), tombrown, tuo zaafi (Ghana); phutu (South Africa); ugali (Kenya); sadza (Zimbabwe); tô (Mali); nsima (Zambia); Asida (Sudan); tuwo (Nigeria); papa (Lesotho); owo, yeke yeke (Benin); soor (Somalia)
	Fermented: Soaking, Fermentation, cooking	Mutwiwa pap, sour sadza (Zimbabwe); afiata, koko, ice kenkey (Ghana); uji, ikii (Kenya); aklui (Benin); ting (Botswana)
Beverages	**Non-alcoholic:** Milling, soaking, Cooking	Akpan (Benin); mahewu (South Africa); munkoyo (Zambia, Zaire); kunnu zaki (Nigeria); kirario (Kenya); borde (Ethiopia); togwa (Tanzania)
	Alcoholic: Germination, Fermentation	Obiolo, pito (Nigeria); busaa, chang'aa (Kenya); pombe, chibuku (Zambia); talla, cheka (Ethiopia); malawa, kidongo (Uganda); doro, chikokivana, kachasu (Zimbabwe); kaffir beer, umqombothi (South Africa).