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REVIEW

JSFA Reports

# Orange-fleshed sweetpotato production: Progress and perspectives for value chain development in West Africa

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## Abstract

Africa and Asia bear the greatest cases of vitamin A deficiency whereas Orange-Fleshed Sweetpotato (OFSP) as a possible solution to vitamin A deficiency, brings income, food and nutritional security for smallholders involved in its production. Reports indicated low adoption of OFSP in West Africa due to poor value chains and wide adoption of White-Fleshed Sweetpotato (WFSP). Here, we reviewed OFSP interventions and programmes undertaken in West Africa, identified constraints limiting OFSP production, and updated the required actions for OFSP value chains development in West Africa. We reported 10 significant interventions and 20 released OFSP varieties within 4 countries. The main bottlenecks to OFSP value chains development are the lack of improved cultivars exhibiting high and stable yield potential, predominance of WFSP, non-exposition of whole population to OFSP varieties, limited number of improved OFSP varieties available, and inadequacy of improved OFSP varieties to smallholder preferences. The roles of donors, research institutions, local partners, and smallholder's contributions in increasing OFSP production and consumption are provided. This will fuel the development of strong OFSP value chains in West Africa.

**KEYWORDS**
orange-fleshed sweetpotato, value chain, vitamin A deficiency, West Africa

## INTRODUCTION

In most developing countries, Vitamin A deficiency (VAD) is of major public health concerns. Statistics about food security and nutrition in West Africa revealed that the number of children under 5 years affected by wasting is 5.1 million; those who are stunted are estimated to 18.5 million; about 1.3 million of those children are overweight and the number of women of reproductive age (15–49) affected by anemia is 41.2 million.[1] The highest rates of VAD occurred in sub-Saharan Africa (SSA) (48%) and South Asia (44%) causing preventable childhood blindness and the risk of death from childhood illnesses such as diarrhea.[2] During the vitamin A supplementation program in 2018 only 61% of targeted children in 17 out of 54 priority countries received two dose coverage as recommended. More than one third of children in need are not receiving the life-saving benefits of Vitamin A supplementation.[3] In addition, West Africa is regarded as home of households under severe poverty with poor access to nutritious foods and lack of knowledge on how to value available resources to improve their nutritional status.[4] Among these resources, roots and tubers appear to be the major source of sustenance for many producers in West Africa.[5]

According to FAOStats (2018)[6] roots and tubers are ranked first in terms of production volume before cereals in West Africa. Among the roots and tubers, sweetpotato (*Ipomoea batatas* L) is the third after cassava (*Manihot esculenta* L.) and yam (*Dioscorea* spp.) in terms of production and consumption volumes. Sweetpotato plays an important role in human and animal nutrition since it is rich in carbohydrates, vitamins (Vit C and Pro Vitamin A), minerals (potassium, magnesium, and calcium), and various

  

**TABLE 1** Number of people (in millions) affected by selected forms of malnutrition, sweet-potato production (in tons), and vitamin A intervention in selected West Africa countries[1,14]

| Countries | Wasting (children under 5 years) | Stunted (children under 5 years) | Overweight (children under 5 years) | Anemia (women of reproductive age 15–49) | Interventions to address VAD | Sweet-potato production |
|---|---|---|---|---|---|---|
| Benin | 0.1 | 0.6 | <0.1 | 1.3 | fVO[a] | 64,659 |
| Burkina Faso | 0.3 | 0.7 | 0.1 | 2.1 | fVO[a], bSP[b] | 64,537 |
| Carbo Verde | n.a | n.a | n.a | <0.1 | n.a | 5434 |
| Côte d'Ivoire | 0.2 | 0.8 | 0.1 | 2.9 | fVO[a] | 54,625 |
| Ghana | 0.2 | 0.7 | 0.1 | 3.3 | fVO[a], fW[a], bSP[b], bM[b] | 150,926 |
| Guinea | 0.2 | 0.6 | 0.1 | 1.5 | fVO[a] | 265,268 |
| Liberia | <0.1 | 0.2 | <0.1 | 0.4 | fVO[a], fS[a] | 26,141 |
| Mali | 0.4 | 1.0 | 0.1 | 2.0 | fVO[b], bM[b] | 504,557 |
| Mauritania | 0.1 | 0.2 | <0.1 | 0.4 | fVO[a] | 4798 |
| Niger | 0.4 | 1.7 | <0.1 | 2.1 | fVO[a], fS[a], bSP[b] | 129,959 |
| Nigeria | 3.4 | 13.9 | 0.5 | 21.1 | fVO[a], fW[a], bSP[b], bM[b], bC[b], bP[b] | 4,070,534 |
| Senegal | 0.2 | 0.4 | <0.1 | 1.9 | fVO[a], bSP[b], MNP[b] | 72,000 |
| Sierra Leonne | 0.1 | 0.4 | 0.1 | 0.8 | fVO[a], bC[b] | 157,033 |
| Togo | 0.1 | 0.3 | <0.1 | 0.9 | fVO[a] | 8551 |

Abbreviations: bC, biofortified cassava; bM, biofortified maize; bP, biofortified plantain/banana; bSP, biofortified sweet-potato; fMG, fortified margarine; fVO, fortified vegetable oil; fS, fortified sugar; fW, fortified wheat flour; MNP, micronutrient powders.
[a]Mandatory program.
[b]Voluntary program.

bioactive compounds (phenolic acids and anthocyanins).[7,8] In most West Africa countries, sweetpotato is used in various food preparations as substitute to rice, cassava, yam and plantain.[9,10] Some authors reported the use of sweetpotato for industrial purposes and its high contribution to food security and animal feed.[11–13] FAOStats (2018)[6] revealed 5,502,647 tons of sweetpotato root production in West Africa from countries such as Benin, Burkina-Faso, Carbo-Verde, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo. At the same time, high number of people in these countries are still suffering from selected forms of malnutrition (Table 1).[1,14]

Within sweetpotato, some important varietal groups can be distinguished based on the fleshed color such as white and cream-fleshed varieties for high carbohydrates, yellow and orange-fleshed varieties for pro vitamin A, and purple-fleshed varieties for anthocyanins.[8] In most developing countries, white-fleshed sweetpotato (WFSP) landraces are predominant and grown in marginal soils under low-input subsistence farming systems.[15] The high adoption of WFSP over orange and yellow-fleshed sweetpotato (OFSP, YFSP) landraces might be due to their food cultures and the high dry matter content of that landrace. During the last decade, the OFSP varieties mainly characterized by the presence of β-carotene have been promoted in sub-Saharan Africa.[16,17] β-carotene functions are related to provitamin A supply, embryonic development, growth and sight correction, genes inhibition, anticancer and antioxidant properties.[18] The use of OFSP to combat VAD makes sense because households used to produce and consume sweetpotato roots before, and it offers a cost-effective and sustainable approach in contrast to expensive synthetic β-carotene with a carcinogenic activity.[18,19]

The development and delivery of OFSP is presented in three phases including (a) the period of OFSP potential recognition (1991–2000), (b) the period of evidence base building (2001–2009) and (c) the period of investment in OFSP research dissemination and advocacy (2009-up to day).[20–22] During the period of OFSP potential recognition, it was possible to convince farmers to produce OFSP for their children, to select some "best bet" varieties with high yield developed outside of Africa, and to engage OFSP breeding for Africa. The period of evidence base building stands for agriculture sensitive to nutrition intervention that can increase the dietary intake of micronutrients in Africa.[23,24] Since 2009 up to now, the focus is on the dissemination of improved OFSP variety in SSA. Significant investments in sweetpotato were initiated to ensure the exploitation of the full potential of OFSP. As a result, a number of superior OFSP cultivars with the potential to improve human nutrition has been released in SSA countries.[22,25,26] Some OFSP varieties were released in eastern and southern Africa (ESA); and very few in West Africa.[21,27–30]

Today, OFSP production and consumption in West Africa is hampering by poor value chains where some important questions remain unanswered or partly answered to plan the way forward. Thus, the current review paper aimed at capitalizing the efforts made in OFSP development and delivery in West Africa in order to identify the gaps of knowledge and required actions for efficient OFSP value chains development. The paper provides a strong literature on the status of OFSP (a neglected crop) in targeted and potential western African countries along with a guideline for OFSP value chains development.

## METHODOLOGY

This review research was conducted on the basis of the following research questions: (1) *what is the extend of previous actions to promote OFSP in West Africa*?, (2) *what are the current challenges related to sweetpotato production situation that hampering the full adoption of OFSP varieties in West Africa?*, and (3) *how OFSP value chain can be developed in West Africa so that its production will provide food and income to smallholder farmers*?. To provide clear answers to these questions, a total of 10 projects related to Ghana, Nigeria, Burkina-Faso, Côte d'Ivoire, Niger and Benin were identified and used in this review. Five online databases (FAO, SPHI, Sweepotato Catalog, UNICEF, and WHO) were accessed. 75 additional scientific documents were selected from Google scholar and PubMed. The keywords used to find the scientific documents included "Vitamin A deficiency", "beta-carotene in sweetpotato", "OFSP development", "OFSP delivery in Africa", "OFSP in West Africa", "OFSP breeding", "OFSP production and sales", "OFSP vines production and dissemination", "OFSP crop management", "OFSP marketing", "OFSP processing", "OFSP storage", "OFSP nutrition and use", "nutrition education", and "knowledge sharing." Scientific papers published in non-reliable journals were discarded.

## PROGRESS IN OFSP DEVELOPMENT AND DELIVERY IN WEST AFRICA

Most actions related to OFSP in SSA were initiated during the period of investment in OFSP research dissemination, and advocacy (2009-up today). Low et al.[22] summarized activities in this period in three main points including major investment breakthrough in synchrony with (i) an enabling environment, (ii) addressing of the key bottlenecks to exploiting OFSP's full potential, and (iii) tackling diversified use of the future growth market for OFSP in SSA. Most donors and/or partners funding or managing projects related to OFSP included the Bill & Melinda Gates Foundation, Alliance for a Green Revolution (AGRA), the Scaling-up Nutrition (SUN), Irish Aid, DFID (UKAID), USAID, United Kingdom hosting a global Nutrition for Growth, and some non-governmental and research organizations. The key bottlenecks to exploiting OFSP full potential were among others the lack of (i) adapted OFSP varieties, (ii) sustainable seed systems, and (iii) qualified human resources for scaling activities. It is worth to emphasize that in many African countries there was no well-established sweetpotato breeding program before 2009. In West Africa, some breeding efforts were initiated to exploit the broad genetic diversity of sweetpotato germplasm to produce new and locally adapted varieties.[31–33] The Sweetpotato Support Platforms in Ghana and Alliance for a Green Revolution in Africa (AGRA) investigated the development of high dry matter and low sweetness OFSP genotypes.[21,32] In addition, 10 significant agriculture sensitive to nutrition interventions have been completed and other are still ongoing with the aim to improve not only OFSP production and consumption for food but also nutrition security among population in West Africa (Figure 1).[27,34,35]

The OFSP interventions in West Africa focused on countries such as Ghana, Nigeria, Burkina-Faso, Côte d'Ivoire, Niger and Benin, and aimed at raising awareness of population (mainly the vulnerable population) through market sensitization, demand creation campaigns, and nutrition education and training.[27] The interventions areas also included breeding, vine dissemination, marketing, processing, storage, and nutrition education. For instance the Sweetpotato Action for Security and Health in Africa (SASHA) project initiated the breeding and prospects for low sweet OFSP and the evaluation of OFSP clones

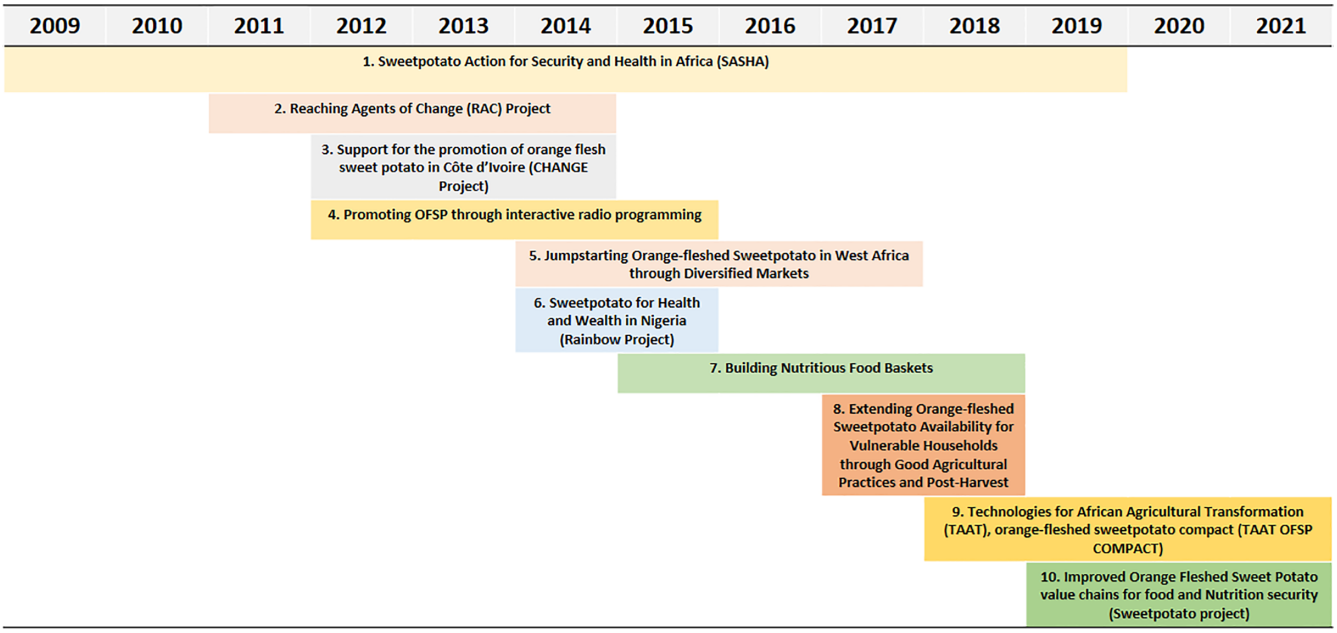


**FIGURE 1** Major OFSP projects in West Africa from 2009 up to 2019

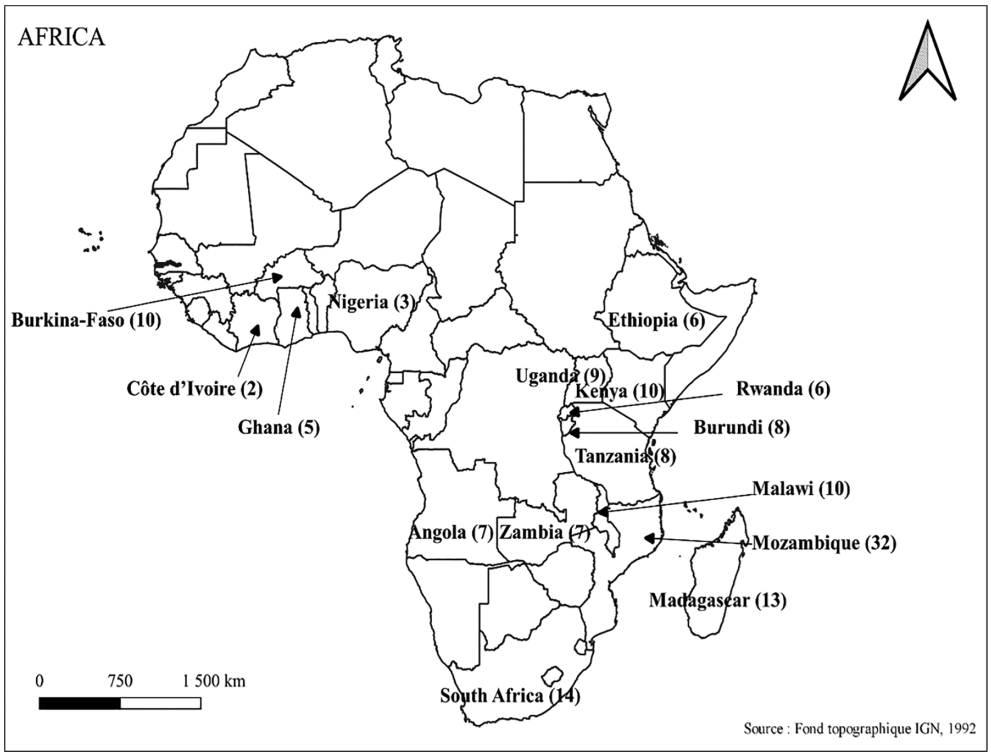


**FIGURE 2** African countries with released Orange fleshed Sweetpotato varieties according to SPHI (2019).[45] Figures in brackets indicate the number of released varieties

in Ghana,[36] and the establishment of sustainable production of pre-basic seeds, and the building of evidence based for OFSP marketing in Nigeria.[37] Reaching Agent of Change (RAC) project in Nigeria built the capacities of the Agricultural and Rural Management Training Institute (ARMTI) to produce clean OFSP planting materials to decentralized vine multipliers with an introduced variety UMUSPO3 (Mother's Delight) and developed variety UMUSPO1 (King J). Training manuals on OFSP project planning, implementation, monitoring, and evaluation learning module were also developed.[38–41] The project "Jumpstarting OFSP in West Africa through Diversified Markets" influenced the behavior of households in Nigeria, Ghana and Burkina Faso to grow and consume OFSP through market sensitization activities, media campaigns, systematic training on good agronomic practices, and decentralized vine multiplication enterprise creation.[27,42] The project Extending OFSP Availability for Vulnerable Households through Good Agricultural Practices (GAPs) and Post-Harvest in Ghana reached 207 males and 138 females on improved practices for crop husbandry and OFSP postharvest handling and storage.[43] Farmers were able to produce OFSP using GAPs and to store the roots in dry sand for 18 weeks with only 21% losses so that stored roots can be used either as food and/or planting materials at the end of the storage period.[44] Since 2019, "the Sweetpotato Project" (2019–2021 with a budget neutral extension until 2022) being implemented in Nigeria, Benin and Niger targets the development of OFSP value chain.

OFSP varieties were released in Ghana, Nigeria, Burkina-Faso, and Côte d'Ivoire.[45] In Ghana, the Crops Research Institute (CRI) introduced Beauregard, Resisto, CIP 442850, and CIP 443035, developed and released Bokye, Apomuden.[46] In Nigeria, three OFSP varieties named Mother's Delight, King J and Solo Gold (UMUSPO4) were released by the Agricultural and Rural Management Training Institute (ARMTI). In Burkina-Faso, TIB-440060 and Caromex varieties were preliminary introduced from East Africa. Then, many other genotypes were developed and evaluated by the Environmental and Agricultural Research Institute (INERA).[47] Most of them have been introduced to Côte d'Ivoire for yield evaluation and farmers preference.[48] Up to 2019, Sweetpotato for Profit and Health Initiative (SPHI) has registered 150 OFSP varieties released in Africa within 16 countries (Figure 2) from which 130 were released in ESA and only 20 in West Africa.[45]

## CHALLENGES FOR OFSP IN WEST AFRICA

The OFSP interventions in West Africa are limited and need to be strengthened with a clear and strong value chains development. There is evidence that OFSP landraces exist but underutilized in some West African countries. Some collected OFSP landraces included Nasamu-red vine in Ghana,[49] BF82, BF92 in Burkina-Faso,[47] Loki kpikpa, Mansawin, Dokouin C, Carrotti in Benin,[50] and Kwara in Nigeria.[31] Only white and yellow fleshed varieties were reported in Niger from the preliminary results of Sweetpotato Project. The challenges associated to sweetpotato value chains development in West Africa can be summarized into five main points: (i) lack of improved cultivars exhibiting high and stable yield potential, (ii) predominance of WFSP in terms of production and consumption, (iii) limited number of improved OFSP varieties available to farmers, (iv) inadequacy of improved OFSP

varieties to smallholder preferences, and (v) non-exposition of whole population to OFSP varieties in West Africa countries.

## Lack of improved cultivars exhibiting high and stable yield potential

According to the FAOStats (2018)[6] (Table 2), Africa is ranked first in terms of total sweetpotato harvested area with very low yield. West Africa is listed as second largest sweetpotato producing region with relatively low yield after East Africa. Such reported low sweetpotato yields in West African countries ranged from 1.8 to 7.4 t/ha. For improved OFSP, reported field yields were estimated below 6 t/ha in Nigeria,[51] and 10 t/ha in Ghana.[52] There is a need to improve local cultivars exhibiting high and stable yield potential to substitute low yielded varieties predominantly used by farmers for root production.

**TABLE 2** Sweetpotato area harvested and yield per regions[6]

| Regions | Area harvested (ha) | Yield (t/ha) |
|---|---|---|
| World | 8,062,737 | 11.4 |
| *Africa* | *4,599,723* | *5.65* |
| America | 346,009 | 12.14 |
| Asia | 2,957,676 | 20.5 |
| Europe | 3775 | 24.75 |
| Oceania | 155,555 | 6 |
| East Africa | 2,184,995 | 7.9 |
| Middle Africa | 401,894 | 6 |
| North Africa | 28,899 | 22.1 |
| South Africa | 31,885 | 2.7 |
| *West Africa* | *1,952,049* | *2.8* |

Unfortunately, there are few studies on sweetpotato cultivars selection and development in most of the major sweetpotato producing areas in developing countries[53]; and other bottlenecks for sweetpotato breeding success includes self and cross incompatibility, limited flowering ability, and limited number of seeds (≤2) per successful crossing.[54,55]

## Predominance of WFSP in terms of production and consumption

There is strong evidence that white-fleshed sweetpotato varieties are predominant in developing countries market while orange-fleshed sweetpotato varieties are predominant in US markets.[56] For instance, about 70% of WFSP against 3.92% of OFSP varieties were reported in Benin.[50,57] In that country, farmers grow other landraces such as cream-fleshed landraces sweetpotato that are typically less nutritious. The core collection from Southeastern Nigeria used by Nwankwo et al.[58] showed 80% and 20% of white and cream-fleshed, and yellow-fleshed varieties respectively. A study in Ghana revealed 41.40% white and cream-fleshed sweetpotato, 35.60% yellow-fleshed sweetpotato, and 23% orange-fleshed varieties.[59] White-fleshed sweetpotato varieties are widely used for daily consumption because they are aligned with the food culture of African local communities basically for attributes such as low sugar content,[60] drought tolerance,[61] resistance to pests and diseases,[62] and high yield and dry matter content.[63]

## Limited number of improved OFSP varieties available to farmers in West Africa

The number of varieties available and accessible is a very important factor in the decision of farmers to produce or not a given variety.

**TABLE 3** Countries with OFSP varieties added to the sweet potato catalog

| Regions | Country | Number of released OFSP | Released OFSP varieties |
|---|---|---|---|
| East and South Africa | Mozambique | 16 | Alisha, Amelia, Anamaria, Cecilia, Delvia, Erica, Esther, Irene, Ivone, Jane, Lourdes, Melinda, Namanga, Sumaia, Tio Joe, Victoria |
| | Malawi | 5 | Anaakwanire, Chipika, Kadyaubwerere, Kaphulira, Zondeni |
| | Zambia | 2 | Chumfwa, Olympia |
| | Uganda | 6 | Ejumula, Gerald, Joweria, Kabode, NASPOT 8, Vita |
| | Kenya | 2 | Kenspot 5, SPK 031 |
| | Tanzania | 1 | Kiegea |
| | Ethiopia | 2 | Kulfo, Tulla |
| | Rwanda | 1 | Terimbere |
| West Africa | Burkina Faso | 1 | Heere |
| | Nigeria | 1 | King J |
| | Côte d'Ivoire | 1 | TIB |
| | Ghana | 1 | SARI-Nan |
| Outside Africa | Peru | 3 | CIP199062.1, Gihingumukungu, Mother's Delight |

Compared to the number of WFSP available to farmers in West Africa, the number of OFSP available is very limited to induce the substitution of WFSP by OFSP. For instance high number of WFSP landraces ranging from 2 to 11 cultivars per village in southern Benin[64] 2–6 cultivars per village in northern Benin[65] was reported. The SPHI project reported 20 improved OFSP varieties released in West Africa of which 4 were added to the sweetpotato catalog.[45] The sweetpotato catalog comprises majority of varieties that are either released and grown by farmers in SSA or about to be released in a country in SSA. From 2005 to 2019 the number of OFSP added to the sweetpotato catalog in SSA increased from 6 to 42 of which 39 were released in twelve African countries and 3 outside of Africa (Table 3). A total of 28 varieties from West Africa were reported in this catalog. Among the 28 varieties, 56%, 28%, and 16% are white and cream-fleshed, yellow-fleshed and orange-fleshed respectively.[66]

**TABLE 4** β-Carotene and dry matter content of the OFSP varieties released in West Africa and added to the sweet potato catalog

| OFSP added to SP catalog | Bêta-carotène content (mg/100 g) | Dry matter (%) |
|---|---|---|
| Heere | 20.90 | 17.20[a] |
| King J | 30.49 | 24.80[a] |
| TIB | 18.71 | 22.00[a] |
| SARI-Nan | 38.37 | 25.80[b] |

[a]Low dry matter (<25%);
[b]Medium dry matter (25%–28%).

## Inadequacy of improved OFSP varieties to smallholder preferences

OFSP varieties are mainly characterized by high levels of β-carotene and sugar content, and low dry matter content.[56] According to Adekambi et al.,[27] OFSP traits for an increase in OFSP adoption are country-specific. For instance, Baafi et al.[32] reported high dry matter and low sugar content as key attributes for the adoption of OFSP in Ghana, whereas in Nigeria, high yield, and high dry matter were the key attributes.[31] These attributes are reinforced by the fact that, in most West African countries, high dry matter content attribute is preferred in food cultures. Unfortunately, most OFSP released varieties in West Africa and listed in sweetpotato catalog have mostly low dry matter (<25%) (Table 4). Therefore, there is a need to increase dry matter content in OFSP without compromising the β-carotene content through breeding projects. Such initiative would yield OFSP varieties which should be profitable to farmers, acceptable to consumers, and effective in improving vitamin A status.[24] Other determinants factors for OFSP adoption include variety characteristics (maturity period, disease resistance, yield potential, drought tolerance), sensory characteristics of roots (attractiveness, taste, flavor, dryness), farmer's experience (participation in farmer associations, source of extension services, participation in training on agronomic practices, and in cooking demonstrations) and institutional factors.[35]

## Non-exposition of whole population to OFSP varieties in West Africa countries

OFSP promoting activities are flourishing within Nigeria and Ghana compared to Burkina-Faso, and Côte d'Ivoire; in other West African

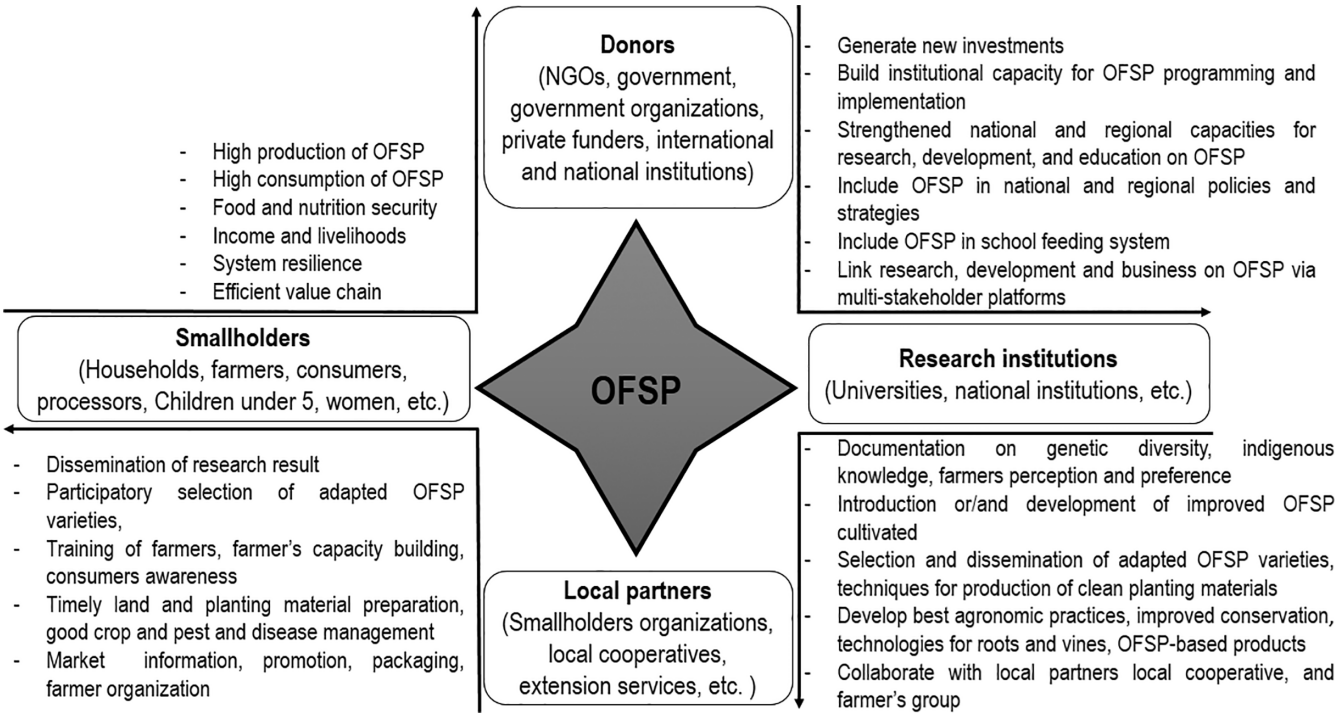


**FIGURE 3** Structure and relationship among stakeholders for full adoption of OFSP in Western African countries

**TABLE 5** Key points in OFSP value chain development and proposed result chain

| Initial situation | Required actions | Outputs | Outcomes | Impacts |
|---|---|---|---|---|
| Predominance of WFSP cultivation | Collection and evaluation of OFSP landraces<br>Introduction of improved OFSP genotypes<br>Development of adapted and high yielding OFSP genotypes | 3/more OSFP varieties available | 3/more OFSP varieties cultivated per village | Substitution of already existing WFSP with best OFSP<br>Increase of OFSP harvested area and production |
| Predominance of traditional agronomic and storage practices | Production of tissue culture plantlets of 2/more OFSP varieties and protected basic planting material in screen houses<br>Training of extension agents on good agronomics practices about OFSP | Distribution of disease-free OFSP planting material (>10,000 households)<br>Existence of >50 agricultural qualified staff familiar with OFSP and VAD | All farmers use and purchase OFSP disease-free planting materials<br>>60% of farmers knowing how to produce and conserve OFSP vines and roots between seasons | Increase of OFSP yield<br>Improvement in agronomic and storage practices |
| Poor knowledge on the evidence of VAD, and nutritious foods | Creation of awareness of the benefits of consuming OFSP | Children under 5 and pregnant women feeding guidelines have been introduced and are utilized; | >60% of target population has awareness about OFSP and is consuming a balanced diet | Regular and comprehensive monitoring and evaluation of food-based approaches for tackling VAD |
| Consumption of sweet-potato roots (fresh, boiled, fried only) | Development of OFSP-based products | >2 nutritious infant OFSP flours available | High use of OFSP products diversification by >60% of target population | Recommendation to use infant OFSP flours by caregivers<br>Distribution of infant OFSP flours via pharmacy |
| Local market and informal system for sweet-potato roots sale | Development and sharing of knowledge, skills and practices of fresh OFSP root marketing | Creation of platform and market for OFSP roots trading<br>Creation of startup and local cooperative for OFSP roots processing | Facilitation of OFSP roots trading<br>Increase of OFSP roots demand | Production and availability of OFSP roots all year round<br>Increase of farmers income from sales of OFSP roots |

countries OFSP promoting activities are not perceptible. Nigeria is known among the most sweetpotato producing countries in SSA with most of the states involved in sweetpotato production. However, efforts to disseminate OFSP varieties were limited to few states. For instance, the Jumpstarting project focused only on Osun and Kwara states and there was advocated for replication in other states. This was also the same in Ghana where few areas were selected for OFSP activities. As a consequence, an overall low adoption of OFSP varieties was reported in Ghana and Nigeria. Adekambi et al.[27] suggested that the adoption rates could have been increased by 10% if the majority of the population was exposed to the OFSP varieties. In other countries there were few actions aiming at exposing farmers to awareness, cultivation, and nutrition importance of OFSP varieties; hence the low adoption at priori.

## PERSPECTIVES FOR OFSP VALUE CHAIN DEVELOPMENT

The OFSP interventions in Mozambique and Uganda has been presented as a good evidence focusing on an integrated agriculture-nutrition-marketing intervention.[22] These interventions were characterized by the (i) introduction of OFSP varieties easy to grow, (ii) awareness campaigns among producers, consumers, and caregivers to incorporate OFSP into their diet and (iii) demand creation to commercialize OFSP roots and based products. The potential for increasing OFSP adoption rates in West Africa requires entire value chains consideration, dialog with all key stakeholders including donors, research institutions, local partners, and smallholders as proposed in Figure 3.

A change OFSP value chain model developed by Low et al.[67] suggested that further required actions should focus on eight points, and Stathers et al.[68] presented the characteristics of a good value chains for OFSP in a country. Depending on the initial situation of the country, we proposed required actions along with expected outputs, outcomes and impacts for OFSP value chains development (Table 5). In overall, key actions are among others the improvement of the availability OFSP varieties to farmers and the awareness activities towards consumers and farmers on the benefits of consuming/producing OFSP. The number and the characteristics of varieties were reported as key determinants in the decision of households to adopt OFSP varieties.[69] The importance of improving the availability of adapted OFSP varieties was mentioned during the period of OFSP potential recognition in East Africa.[20,21] The improved varieties generally came from farmers landraces[70–74]; imported cultivars[46,51,75]; and bred cultivars.[31,47,76,77] Since the introduced varieties and local landraces presented some non-preferred traits by stakeholders in OFSP value chains, it

is important to initiate some breeding efforts to improve agronomic and culinary traits, and combined desired traits in one genotype. Awareness creation activities were already reported as a strong way to facilitate both production and consumption of OFSP varieties within eastern African countries.[78,79] Sensitization of local communities should focus on knowledge about Vitamin A (importance of vitamin A, most exposed categories to VAD, VAD prevention, vitamin A rich food items), and awareness on OFSP consumption (nutritional benefits, farming knowledge, cooking knowledge, trading importance). The actions of research institutions are very crucial to generate knowledge and human resources necessary to boost OFSP breeding and awareness in West Africa.

## CONCLUSION

OFSP brings income, food and nutritional security for smallholders. Its adoption is low in West Africa for the benefit of WFSP and hampered by poor value chains. Previous actions focused on activities related to awareness creation in the form of market sensitization and demand creation campaigns, and nutrition education. However, farmers are still confronted by the low yield, the predominance of WFSP, the non-exposition of whole population to OFSP varieties, the limited number of improved OFSP varieties available, and the inadequacy of improved OFSP varieties. All stakeholders should interact to generate new investments and policy change, develop adapted OFSP genotypes from the local genetic pool available for different production areas and make them available to smallholders. A successful and sustainable OFSP value chains should ensure disease-free OFSP planting materials production and fully available in time and affordable to farmers.

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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

### AUTHOR CONTRIBUTIONS

Sohindji S. Fernand wrote the draft. Adje O.A. Charlotte, Fassinou Hotegni V. Nicodème, Nadia Fanou Fogny, Akponikpe Tania, Quenum Florent and Enoch G. Achigan-Dako participated in revising the manuscripts. All authors read and approved the final manuscripts.

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