Feed Grains as a Secondary Market for Sorghum in Mali?

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Abstract

The substantial increases in production and productivity of maize over the last two decades have facilitated the rapid growth of the poultry sector in Mali and consistently been sold below the price of sorghum. Sorghum without tannin has been demonstrated to be an excellent feed but slightly inferior to maize. To substitute sorghum for maize large decreases in the relative price of sorghum to maize are necessary.

As the demand expands for feed, cereal production will increasingly need to come from regions north of the prime cotton zones. In these drier conditions sorghum’s greater tolerance to low and variable rainfall and to lower soil fertility will give sorghum a productivity advantage over maize. Given the larger area over which sorghum is produced sorghum costs can become competitive with maize without reaching the same high yield levels as attained in maize in the south. Fifty percent yield gains in sorghum have been demonstrated in Mali in our pilot project as averages for farmers’ associations in several years (Tahirou et al., 2008; Tahirou et. al.,2009; Coulibaly et. al., 2013; Coulibaly et. al., 2015). The IICEM program has further diffused our program in 2010-2012 over a wide area of the south of Mali.² The cost competitive position of sorghum for feed would also be aided by removing the export prohibitions on maize.

Meanwhile the higher prices for sorghum than of maize in spite of impressive increased production gains of sorghum indicate the continuing importance of sorghum (and millet) as human foods especially with decreases in supply from the disruption from the war in the north of Mali (2012), the coup and later removal of Sanogo from the military command (2012 and 2013), and the dry weather of 2013..

As incomes increase in the development process consumers shift from a predominant consumption of cereals and tubers to fruits, vegetables, meat, milk and cheese. The most rapid growth in this process is for broilers as chickens pass from an expensive meat for wealthy people and special occasions to a staple for lower and middle income consumers. The broiler sector in Mali is increasing rapidly but is incurring high costs now with poor quality protein sources, irregular quality domestic concentrate, and expensive imported concentrates. Moreover, there is concern with improving the quality of the maize (50 to 60% of the ration) by avoiding maize with impurities and molds.³

Introduction

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² Results for the combined effects of our program and the IICEM program for millet in Mopti are reported in Sanders, Harman, Ouendeba and Traore, 2015. The evaluation for the impact of the sorghum program as of 2015 is programmed for the fall of 2015.
³ This is an especially serious problem for those chicken producers importing maize from the coastal countries with their wetter, hotter conditions.
The focus of this paper is on what will happen as sorghum productivity is increased especially looking at a potential secondary market, feed grains, to cushion or eliminate the price decline from productivity growth.

Sorghum and millet are the predominant cereals for human consumption in Mali. As productivity is increased it is possible to avoid or at least moderate the price collapses that occur both in good rainfall years and as technology is successfully introduced. The development of secondary markets can play this function. In millet there is a small but increasing sector of food processors of traditional millet products in urban centers. For sorghum there is the potential demand for feed grain.

For most of the 21st Century in Mali the cost advantage in feed has been with maize rather than sorghum. Maize has benefitted from substantial gains in yields with new cultivars, higher fertilization and improved agronomy. In contrast sorghum yields have been stagnant (Figures 1 and 2). Moreover, various government policies including export bans and selective subsidies for maize and less subsidization of input costs for sorghum relative to maize have also helped keep the price of maize down.

Nevertheless, in semi-arid regions all over the world sorghum is produced as a substitute for maize in the feed. In the drier environments of Mali outside of the prime cotton areas of the south the greater tolerance of sorghum and millet to lower and more irregular rainfall and to lower soil fertility make these crops more appropriate for the climatic-soil conditions in much of the country than maize. The first requirement for sorghum to be price competitive with maize is then to increase sorghum yields. Changing the public policies, which reduce the costs of maize relative to sorghum would also help.

Besides the substitution potential of sorghum for maize in the ration this paper is also concerned with the growth of the broiler sector and the modernization process of the intensive poultry sector in Mali.

The Success of Maize and the Expansion of the Poultry Sector

In West Africa the most rapid increase in cereal production since 2000 has been in Mali (Mali Best Report, 2015, p.11). From 2000 to 2013 maize production has increased at a 17% annual growth rate, faster than any other cereal and is now consumed at 35 kg/person year, the forth cereal in importance in Mali (Mali Best Report, 2015, p. 28). Yields increased from slightly over one ton to almost 3 tons in 2014 (Figure 1). From the early ‘90s maize production accelerated from less than 200 tons to almost 2 million tons in 2014, a tenfold increase (Mas Aparisi et al, 2013, pp. 7 and figure 2).

In the 21st Century maize has been the “go to” crop in the cotton sector. When farmers were unhappy with the low prices or late payments for cotton, they planted less cotton and/or diverted more of the cotton fertilizer for the maize and later sorghum. CMDT (the cotton monopsony) made this diversion of their cotton credits to the cereals into a virtue by advocating diversification. Maize production is concentrated in the higher rainfall south with an estimated 80% in the Sikasso region (Mali Best Report, 2015, p. 28).
Maize production and productivity gains in the last twenty-five years have made available low cost maize and facilitated the rapid growth of the Malian poultry sector. The association of poultry producers (FIFAM) states that there are 2,670 intensive chicken producers in 2014 as compared with 216 in 1999 (1999 estimate of Chemonics; cited from Berthe, 2015, p.2). Maize is 50 to 60% of the feed volume and feed costs; thirty percent of maize production goes for feed principally for poultry (Mali Best Report, 2015, p. 29).

With these rapid gains in production and yields Mali could be exporting to the region. However, there has been little trade in maize in comparison with the total production. In peak years for trade exports were 3% of production in 2004 and imports were 2% of production in 2005. After 2006 export bans led to international exchanges of maize of less than 0.5% of maize production according to official data though some smuggling continued (Mas Aparisi et al, 2013, p.11). So both rapidly expanding productivity and trade restrictions reduced the domestic price of maize and facilitated the growth of intensive poultry production.

In contrast sorghum yields stagnated at one ton/ha (Figure 1). But after 2008 sorghum production was substantially increased reaching 1.5 million tons in both 2009 and 2014 though falling below that in the intervening years (Figure 2). Attaining these high production levels without a complete price collapse indicates the continuing importance of the demand for sorghum as a human food.

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**Figure 1. Maize and Sorghum Yields(tons/ha) in Mali, 2006-2014**

Source: ADA (Directorate of National Agriculture), unpublished data, 2015

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4 In earlier trips we learned of Nigerien traders buying and exporting maize to Niger from the main export site of maize for Niger, Koutiala

5 Defined as egg and broiler production produced in confined conditions with feeds (concentrates, protein sources, cereal).
The Potential Demand Growth of Sorghum as a Feed

Maize future productivity gains will need to be concentrated in the higher rainfall cotton south. Moreover, maize has already obtained high yield gains there including the introduction of hybrids. Sorghum is just beginning this process in Mali but has made rapid yield gains in other countries based upon these same inputs.\(^6\)

Fortunately for the prospects of increasing sorghum productivity there is a substantial yield gap that still exists for sorghum between the farm level and the experiment station yields. Moreover, yield increases of 50% for sorghum and millet technology with open pollinated cultivars and inorganic fertilizer have already been demonstrated in both pilot projects and on moderately large areas and these yield gains have been shown to be profitable both in the cotton zone and in drier regions over several years (F. Baquedano et. al., 2010; J. Coulibaly et.al., 2015; J. Coulibaly et. al., 2013; Vitale and Sanders, 2005).

So if there are good prospects for increasing productivity and decreasing the costs of sorghum, what is the substitution relationship of sorghum for maize as a feed? Sorghum has a feed efficiency of 95 to 97% of that of maize (J. Hancock, conversation, 2014; also see Tandiang et al., 2014; Clement et al., 2010; Carmencita and Nelia, 2006; Parthasarathy et al., 2005; and Dowling et. al., 2002; and Hancock, 2000). Therefore at a price of 95% of that of maize equal expenditures for the two cereals would result in equivalent productivity gains (weight gain in broilers and rate of egg production in layers). At a lower price for sorghum than 95% of the maize price the advantage in the feed would be that of sorghum.\(^7\)

With rapid supply increase in broilers and falling prices of chicken, poultry producers are very sensitive to small price changes if they know that productivity can be maintained.

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\(^6\) From the late ‘50s in 14 years national sorghum yields were tripled in the US so a substantial response has been demonstrated from new cultivars, increased fertilization, and better agronomy (Miller, F.R. and Y. Kebede, 1987).

\(^7\) For sorghums without tannin. Later we will discuss tannin.
When maize prices reached 118,000 to 131,000 fcfa/sack in 2008 and stayed high in the winter of 2009, there was a cost advantage to using non-tannin sorghum from June until September of 2008 (Figure 3). In July and August the sorghum price was only 90% of the cost of maize. Unfortunately, almost all the chicken producers interviewed did not even know about this potential of substituting for maize with sorghum. This also included the veterinarians and other feed specialists making recommendations to the poultry producers on feed composition. So the problem is not just with relative costs but also with the knowledge even among specialists about the feed value and substitution potential of sorghum.

Source: OMA (Observatoire du Marché Agricole), monthly data.

a. Note that it would have been more appropriate to use wholesale prices as most of the chicken producers bought from wholesalers though some did buy from farmers. So we had to assume that marketing margins did not reverse this relationship.

After this brief period with lower costs in 2008 sorghum has again been losing the competition with maize as the lowest cost cereal for the feed. In most of the 21st Century maize has had a cost advantage over sorghum. Moreover, in 2014 with another production and productivity jump for maize from 2010 to 2014 this price ratio reached and stayed above 1.2 (Figure 4). The sorghum price was 20% more than that of maize in most of 2014 rather than the goal of 5% percent below. To expand the demand for sorghum this cost advantage of maize needs to be reversed along with making information on sorghum substitution potential available to chicken producers and their technical advisers.
Sorghum has performed poorly in increasing productivity but can be grown over wide areas of the country. Substantial yield gains have been demonstrated on farmers’ fields in pilot and development projects. So implementing further development with improved seed production and credit for inputs as has been done with maize and rice is feasible. With the further rapid expansion of the poultry industry there will be a strong continuing demand for cereals as feed. Meanwhile maize breeders search for early and very early (drought escape) cultivars and do more basic research on drought resistance on maize while sorghum and millet already have these characteristics.

**The Economics of Sorghum Competing as a Feed**

Returning to the original problem of what happens if the productivity of sorghum is substantially increased. Fortunately, there are two favorable outcomes from increasing the productivity of sorghum. First, as sorghum yields are increased but the price ratio continues to favor maize: This could result if there were continuing productivity gains in maize. In this case consumers will benefit from the lower sorghum prices. Mali still has substantial malnutrition problems and population growth is very high at 3.6% (Malian estimate of population growth quoted in Mas Aparisi A., Diallo F., Balié J., 2013, p. 9). The World Food Program (PAM) and the government acquisition and distribution program (OPAM) concentrate on purchasing sorghum and millet to stimulate production of low income farmers while also distributing to the nutritionally needy. OPAM is also concerned with amassing a storage stock to respond to adverse climatic events. In 2013 PAM purchased 20,262 tons of sorghum and millet and in 2014 OPAM was planning to acquire 35,000 tons of these two cereals (Mali Best Report , 2015, pp. 26,27). The role of food security is still of primary importance to Mali.

In the second case sorghum productivity is increased and the sorghum price falls to 0.95 or less of the maize price: Below a price ratio of .95 (sorghum price/maize price), there will be an economic incentive to substitute sorghum for maize in the feed. With this increased demand for sorghum the price decline from rapid technology introduction of sorghum or from good weather will be reduced. By raising the expected price for sorghum (decreasing the price collapse) farmers gain higher incomes from the increased demand for sorghum in the feed ration. In both of the above outcomes the increased consumption of sorghum is beneficial to Malian consumers and increases farmers’ incomes.

The second case is more likely and more consistent with the factor endowment of Mali as it is difficult to expand maize productivity outside of the high rainfall zone of the Sahel. Another factor making maize less expensive than sorghum is government policy especially the export prohibitions intensively used after 2006 (Mas Aparisi et al, 2013, p. 11). Moreover, there has been more extensive use of fertilizer subsidies for maize than for sorghum (J. Coulibaly et al., 2015). Eliminating export bans on maize and selective input subsidies would make relative price changes more favorable for the competitive position of sorghum in the feed.

The productivity increases in sorghum by reducing costs per output unit enable the sorghum price to decrease with farmers initially making a profit from the lower costs in spite of lower prices. The

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8 Another adjustment to falling prices from higher productivity is that farmers can reduce their area in sorghum and plant other crops. With increased productivity, costs per unit of output are reduced so farmers still make a profit with reduced prices until many farmers adopt and then the benefits are concentrated among consumers.

9 Note how small these levels are compared with the 1.5 million tons of sorghum (Figure 2).
secondary market of sorghum in the feed ration then would put a floor on how much the sorghum price declined. The elimination of export prohibitions and selective subsidies would raise the price of maize relative to sorghum. So all these factors make feasible the substitution of sorghum for maize in the ration. So what does our economic model look like?

\[
\frac{P_s}{P_m} \leq 0.95 \quad a
\]

Once the sorghum price falls to 95% of the maize price equal expenditures on the two cereals result in equal feed efficiency, the same amounts of weight gains in broilers or egg productivity of layers. Before declining to the point “a” the demand curve for sorghum is the vertical axis or zero sorghum as there would be no productivity gain from switching just higher costs. Once the price falls below “a” the profit maximizing chicken producer should switch to sorghum. This assumes that the intensive chicken producer is informed about the productivity of sorghum as a feed and that adjustment costs of switching feeds are not large. Information is critical as not even his technical adviser has been alerting him about the potential of sorghum. But the adjustment costs are expected to be minimal with some changes in suppliers and quantity adjustments in the feed (see Appendix A for further elaboration of demand shifts for maize as a feed before .95 and for sorghum thereafter).

Meanwhile we need to return to several other factors affecting feed choice and the evolution of the poultry industry in Mali.

*Cereal and Meat Consumption in Mali*

We have noted above the continuing importance of sorghum and millet as human food. So in 2013 sorghum is still more important than maize as a human food. But as with rice and millet this is changing as maize productivity gains reduce relative prices (Figure 6).
Note: Rice provides 20% of food calories, millet 16%, sorghum 14% and maize 11%.

With the low incomes in the country meat consumption is still very low compared with cereals. Nevertheless, poultry consumption almost tripled from 2008 to 2012 and was second to beef in 2012 (Table 1).

Table 1. Meat Consumption (kg/person/year) in Mali, 2012

<table>
<thead>
<tr>
<th>Products</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef kg/person/year</td>
<td>2.60 (65%)</td>
<td>2.48 (70%)</td>
<td>2.84 (69%)</td>
<td>2.78 (63%)</td>
<td>2.84 (66%)</td>
</tr>
<tr>
<td>(% of meat consumption)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mutton</td>
<td>0.78 (19%)</td>
<td>0.28 (8%)</td>
<td>0.37 (9%)</td>
<td>0.43 (10%)</td>
<td>0.35 (8%)</td>
</tr>
<tr>
<td>Goat</td>
<td>0.37 (9%)</td>
<td>0.47 (13%)</td>
<td>0.55 (13%)</td>
<td>0.59 (14%)</td>
<td>0.48 (11%)</td>
</tr>
<tr>
<td>Poultry</td>
<td>0.20 (5%)</td>
<td>0.26 (7%)</td>
<td>0.32 (8%)</td>
<td>0.50 (11%)</td>
<td>0.59 (14%)</td>
</tr>
<tr>
<td>Total meat consumption (kg/person/year)</td>
<td>3.98</td>
<td>3.51</td>
<td>4.11</td>
<td>4.35</td>
<td>4.29</td>
</tr>
</tbody>
</table>
Shifts the Demand for Sorghum as Feed

There are other important factors affecting the shift in demand for cereals in the feed. Maize can get fungi causing myco-toxins in the field whereas sorghum is less subject to afla-toxin in the field. Both are vulnerable in storage and transport especially if they are not harvested and stored sufficiently dry.\(^1^0\)

Afla-toxin has been an important cost to maize. Producers reported chicken losses to “moisissures” (molds) and said they rejected maize with clear mold evidence. There are effective controls now. T5X costs about 1,200 cfa/kg (sold in 20 kg sacks) and is applied at 2 kg/ton either as a prophylactic or a treatment. This is an important innovation favoring maize. Unfortunately many chicken producers even though familiar with the molds are not familiar with these latest techniques for control and some are not selective enough in their choice of maize.

Tannin is a nutritional inhibitor found in sorghum, grapes, cranberries and dark chocolate. It is an anti-oxidant and reduces primarily protein consumptions but this inhibition is associated with other factors (L. Rooney, 2005). Tannins in sorghum can cause problems in the growth of chicks and adolescent chickens (‘poulettes”) but they do not affect adult performance (Sedima\(^1^1\) executives, conversation). Most chicken producers, vets and feed dealers either know about tannins or at least that there are some digestive problems with sorghums. What is not generally known is that with farmer and breeder selection most sorghums\(^1^2\) in Mali and many other countries do not have tannin (Tahirou et al., 2006, pp. 8,9; Rooney, 2006). Still before recommending the substitution of sorghum for maize a supply of a uniform sorghum cultivar without tannin would need to be available for chicken producers so some labeling and extension information will be important.

Qualitative Improvements in chicken production

Intensive poultry production is a difficult skill to master so countries are observed to go through a long process of the prices of chicken relative to other meats falling as this learning by doing occurs. How is this process proceeding in Mali?

There are serious nutritional problems with the two main sources of protein commonly used in the feed. First there is fish meal from Senegal and dried fish from Mali. Fish meal can bring mycotoxins and bacterial infections (salmonella). Cotton seed meal often has too much fiber plus gossypol. Now many better broiler producers are switching to the imported concentrate and just adding maize. Some have been contracting farmers to produce soybeans as a better protein source. But there have been problems with the contracting process and with the necessary treatment of roasting (“torrefaction”).

Many producers of broilers introduce six rotations. Each batch of broilers takes 35 to 45 days depending upon the weight goal. Sometimes this time length is extended for larger weight gains or because there is difficulty in marketing. This reduces the time available for sanitary treatments between rotations. Vets

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\(^1^0\) The bottom of storage or in transport is generally hotter and wetter and thus more subject to mold infection.

\(^1^1\) Principal feed manufacturer in Dakar, Senegal

\(^1^2\) Of the traditional cultivars found in local markets in 2005 seven of the 13 did not have tannins. Nine of the ten improved cultivars did not contain tannin. There were two laboratory tests in Texas A&M and in the Food Technology Lab of the Agricultural Research Institute (IER) of Mali (Abdoulaye and Sanders, 2006).
have told us that this can then result in a build up over time of bacterial and other infections which can ultimately decimate the production.

Finally, both producers and suppliers are now recognizing the importance of clean maize (or sorghum). The small pebbles often found in the maize shorten the life of the feed grinders. Some offering this grinding service to other producers comment that they are reducing this service and just focusing on their own feeds because of the dirty maize they are receiving. Up to 15% impurities have been observed in the maize (field interviews in Bamako). There is a general preference for the yellow maize as the white maize grinds into too fine powder for a good feed.

**Vertical Integration and Efficiency in Feed Choice**

In the modernization of the poultry sector vertical integration is often seen where marketing functions are expanded into the supply chain by the chicken producers or feed dealers. In Central America the large feed dealers even set up their own chicken restaurants in the capitals. Recently in Mali chicken producers have been selling their chicken carcasses at 1400 to 1600 cfa principally to “revendeurs,” who will buy in quantity and distribute the chickens in smaller quantities to hotels, restaurants, and supermarkets. Some chicken producers develop their own clients as at selling points with refrigeration or sell directly to hotels or restaurants (Figure 7). Then they often need transportation and to sell to order, which can means having more than one set of broilers being raised at overlapping times. So there are costs associated with skipping stages in the marketing process. But as the supply of producers is expanding rapidly, prices are coming down so there are increasing pressures to find ways to increase revenues and to reduce costs. Skipping stages in the marketing process is a method of increasing revenues (see Ndoye et.al.,2015 on the secondary market for millet of processed millet products)

**Figure 7. 2015 Prices at the Different Marketing Stages for Dressed Chickens**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Price (CFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer</td>
<td>1600</td>
</tr>
<tr>
<td>Revendeurs</td>
<td>1800</td>
</tr>
<tr>
<td>Selling Point</td>
<td>2100</td>
</tr>
<tr>
<td>Hotels/Restaurants</td>
<td>3000</td>
</tr>
</tbody>
</table>

Source: Survey data reported in Berthe, 2015.

Note: The standard chicken carcass after 35 to 40 days is then 1 to 1.2 kgs
In the modernization process the improved efficiency of the feed with higher dependability and then less disease problem are the most important constraints here. Increasing numbers of producers are taking the simple but expensive route of buying imported concentrate, making sure that their maize does not have mold, and avoiding the domestic protein sources of fish meal and cotton seed meal in their broiler feeds. So this is a high feed cost solution but avoids the problems with the local protein sources and the irregular quality of the domestic concentrate. Quality control of inputs is an important role of the state.

Conclusions:

If Mali reduces the export restrictions on maize and is successful in increasing sorghum productivity, then we would expect sorghum to become more cost competitive as a feed. But with the substantial cost differences and a twenty five year head start, the sorghum yield gains will need to be substantial and widely diffused among farmers for sorghum to become competitive. The feed option is still out there as a possible floor but it implies a large decrease in the relative price of sorghum to maize. On the positive side for sorghum are the much larger areas and numbers of farmers in the country who can increase the productivity of their sorghum as compared with the regional concentration of the maize producers in the prime cotton zone (Sikasso). Moreover, moderate increases in sorghum yields (50%) have been achieved in the field and require much less inorganic fertilizer than normally applied to maize (Coulibaly et al, 2015).

The expansion of sorghum and millet production since 2008 even though based upon area increase indicates that both still have important roles to play as human foods. Large scale sorghum production of 1.5 million tons in both 2009 and 2014 was impressive. The expansion of the World Food Program and of OPAM have been oriented to sorghum, millet and rice to benefit the low income producers in the acquisition process and those with under and mal-nutrition in the delivery process. So in the near term, the next five years, we expect both sorghum and millet to be primarily used as human food and that prices will not fall substantially. If productivity can be increased rapidly, sorghum is expected to be able to compete with maize as a feed especially if export prohibitions are taken off maize. The demand projections for feed use of sorghum indicate 9.7% annual demand growth for sorghum once it reaches the 0.95 threshold (Appendix A). As with maize in the past twenty years this demand growth is principally driven by the rapid income and population growths in Mali.

To improve the productivity of the poultry sector increased concern needs to be addressed to the quality of the components especially the local protein sources and to regulate the quality of domestic concentrates. Development of domestic soybean production for meal as a protein source would be a substantial qualitative improvement in the protein feed options especially for the producers of eggs. Also on the marketing side facilitating the skipping of market stages can serve the same purpose as reducing costs thereby providing more incentives to increase efficiency and size. Skipping marketing stages can involve increased costs so it is not always profitable.

References:

13 OPAM also has an important objective of setting aside a cereal stock to respond to adverse climatic events usually a drought.


Coulibaly, J., G. Kumaraswamy, and J. H. Sanders, 2013.Economic Impact of Sorghum and Millet Technologies in Mali Agricultural Campaign, 2010-11, Bulletin IER-INTSORMIL n° 11, Purdue University, Department of Agricultural Economics, February 2013, 31 pages.


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Ndoye, Ababacar, Botorou Ouendeba, and John H. Sanders, 2015. Demand for Millet Processed Products in Mali and Burkina Faso, mimeo submitted to the Gates Foundation. Purdue University, West Lafayette, IN


Sanders, Joh H., Jean Harman, Botorou Ouendeba and Soungalo Traore, 2015 Introducing New Millet Production Systems in Mali, mimeo produced for the Gates Foundation, Purdue University, West Lafayette, IN.


Appendix A. Estimating the demand increases for cereals in the feed

Above “a” (Figure 5) there is no substitution of sorghum for maize as the cost of sorghum is greater and there is no advantage in the feed efficiency value of substituting sorghum for maize. At “a” the feed efficiency value for equivalent expenditures on either sorghum or maize are equal. Below “a” moving along the demand curve for sorghum “ab” the quantity demanded of sorghum in the feed at the farm level will be determined by the relative prices of sorghum and maize. Now if we add in per capita...
income growth as a shifter as we know that the quantity demanded of chicken per capita will increase substantially with income growth, the equation:

\[
\frac{C}{N} = \alpha \left( \frac{P_S}{P_M} \right)^{-\gamma} \left( \frac{Y}{N} \right)^\beta \tag{1}
\]

Where consumption per capita of sorghum in the feed ration is a function of the prices of sorghum and maize. With a price ratio above .95 of the sorghum price relative to the maize price rational chicken producers would not shift to sorghum so the price term for sorghum is not relevant until this ratio is at or below .95. Once at point “a” a lower price of sorghum relative to maize results in an increased demand for sorghum. Conversely, there is a decreased demand for sorghum as the relative prices change in favor of maize with there being no demand for sorghum above .95. This also assumes that chicken producers are informed about the potential for substitution between the two cereals. Taking the logs and differentiating with respect to time turns the equation into rates of growth over time (2).

\[
\frac{(\partial C/\partial t)/C}{(\partial N/\partial t)/N} = \gamma \frac{\partial P_M}{\partial t} - \gamma \frac{\partial (P_S/P_M)}{\partial t} + \beta \frac{\partial (Y/N)/\partial t}{Y/N} \tag{2}
\]

Finally converting this to total demand growth rate for sorghum in the feed gives us (3):

\[
\frac{\partial C/\partial t}{C} = +\gamma \frac{\partial P_M}{\partial t} - \gamma \frac{\partial (P_S/P_M)}{\partial t} + \beta \frac{\partial (Y/N)/\partial t}{Y/N} + \frac{(\partial N/\partial t)/N}{C} \tag{3}
\]

Once the price ratio is below .95 the rational chicken producer with perfect knowledge of the relative feed values would shift completely sorghum for maize. In reality the acquisition of this knowledge and any adjustment costs would result in a gradual substitution so the estimates here are for a maximum demand growth for sorghum as the information on the feeding efficiency sorghum is made available and is credible to the veterinarians advising the chicken producers on their feed composition. Below “a” the first two terms will be the changes of the growth rate of the demand for sorghum as the prices of sorghum and maize change. The third term on the right hand side picks up the derived demand for sorghum as there is increased demand for chicken in the diet associated with per capita income growth. So the high income elasticities of demand for chicken are reflected here. Finally, the fifth term moves the equation to total rather than per capita growth rates by adding in the effect on demand growth for chicken from population growth.

Returning now to above “a” where the cross price elasticity is zero and the sorghum price has not yet become relevant. So first we estimate the recent growth of demand for maize in the feed while sorghum is still not competitive.

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14 We have already mentioned in the text that chicken producers and their veterinarian or other advisers generally do not know about the potential of non-tannin sorghum to substitute for maize. So even in 2008 when it was briefly advantageous to do so our sample did not report shifts to sorghum. Many of the producers had entered the business after 2008.
Taking out 2012 because of the war and the coup prices of maize came down from 120 to 100 over the period 2008-2014. This is an annual decrease of -3% over this period. With a price elasticity of demand for maize we use -1.2 as this is a derived demand for the demand for broilers. So the price effect had a 3.6% annual increase in the demand for maize as a feed. The effect of population growth was the same as that of the decreased price. But the income growth had the largest effect at 4.8%. The total estimated demand growth for maize was then 12%. So this served as a stimulus for the rapid growth of the poultry sector and moderated the price decline of maize as the production and productivity of maize were rapidly increased.

The above equation becomes meaningful for sorghum once the price ratio reaches 0.95 (“a”). There might be some substitution earlier but it would not be rational. The big question mark is the rate of price decrease. First the prices have to come down to “a”(.95) before it is rational to substitute sorghum for maize. With the rapid expansion of maize production and productivity maize has had the cost advantage. But as the poultry sector continues to expand rapidly maize gains will be constrained moving north out of the prime cotton sector. Moreover, with trade and greater sensitivity of maize to adverse weather especially as maize production attempts to move north, we would expect more yield volatility hence more short term potential for knowledgeable producers to switch cereals source.\textsuperscript{15}

Table A-1. Growth in Demand for Cereal in the Feed

<table>
<thead>
<tr>
<th>Demand for Maize/sorghum</th>
<th>Characteristics</th>
<th>Price Effect</th>
<th>Economic Growth Effect</th>
<th>Population Effect</th>
<th>Annual effect-growth of demand for maize (sorghum) in the feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual demand growth for maize in the feed, 2008-2014.</td>
<td>$\gamma = -1.2; \beta = 1.6$ Cross price and income elasticities for maize as a feed. Population growth rate of 3.6.</td>
<td>3.6\textsuperscript{a}</td>
<td>4.8%</td>
<td>3.6%</td>
<td>12\textsuperscript{b}</td>
</tr>
<tr>
<td>Potential demand growth for sorghum below “a.”</td>
<td>Same elasticities as above but now the demand growth is for sorghum</td>
<td>1.3\textsuperscript{c}</td>
<td>4.8%</td>
<td>3.6%</td>
<td>9.7\textsuperscript{c}</td>
</tr>
</tbody>
</table>

\textsuperscript{a} The growth effect from the changes in the price of maize.

\textsuperscript{15} As in Texas, Kansas and Nebraska we would expect increasing use of sorghum in the feed taking advantage of the ability to produce sorghum (and millet) in the drier regions with lower soil fertility. At a price historically approximately 10% lower than that of maize and less favorable policy incentives sorghum has retained its competitive position for feed in the US.
b. This is the annual increase in demand growth for maize over 2008-2014.

c. This is the effect of the falling sorghum price relative to maize after “a.”

d. Once the ratio fell below 0.95 this became the demand for sorghum as the price ratio continued to fall from .95 to .90 over a five year period. It took five years here to reach 0.95 from a price ratio of 1.21 (average of 2013 and 2014) with a price ratio decline rate of -4.7%. Once reaching 0.95 we assumed that the rate of relative price of sorghum to the maize price relative to maize would slow up to 1.07% in falling from 0.95 to 0.90 over five years. Then we calculated above the annual growth of the demand for sorghum for feed over this five year period by multiplying by the cross price elasticity.

Further Notes: Population growth. Mali is growing at 3.1% according to the World Bank (World Development Report 2014, p. 296). The latest Malian survey shows an even higher figure at 3.6% (Mas Aparisi A., Diallo F., Balié J., 2013, p. 9) Per capital economic growth. In Mali with the war, a coup, and continuing stagnation were −0.44% in 2012 (World Development Report 2014, p. 296). Mali rebounded in 2013 and an optimistic growth rate of 6.6% results in in per capita growth of 3%.

After reaching .95 if over the next five years the price falls to .9, the rate of relative price decline would be 1.07%. With a cross price elasticity of -1.216 this would be a relative price term increasing the demand for sorghum for substitution of maize at 1.28% annual growth for sorghum demand. Note that this total demand growth is driven principally by the economic and population growth. As with maize the price term has much less effect in increasing the demand for sorghum than the income effect. The sorghum price effect is also only half the population growth effect. Nevertheless, this 9.7 percent annual growth of the demand for sorghum in the feed is impressive.

The critical thing for sorghum is to increase yields and reduce the relative price of sorghum to maize so that the switchover to sorghum is encouraged. The positive potential of this growth results from the advantage of sorghum over maize moving north as the demand for chicken continues to increase rapidly.

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16 In the interviewing we attempted to estimate chicken producers’ cross price elasticities of demand. From their answers and we ended up roughly dividing responses into two groups. we divided producers into two groups. The first group we called the perfect knowledge group. They would not switch at all unless they were assured that they could attain nutritional equality with maize. Then they would switch entirely with small price changes below the 95%. Since perfect knowledge or large scale shifts are both unlikely we present here the response of the group that gets neutral information from their vet or other specialist. Rather than tell them only to use maize as almost all the vets and other technical support staff do presently, they get neutral information between the two cereals. The vets recognize near equality in nutrients but do not make recommendations. Even with this scenario the cross elasticities were incredibly high due to total switching so we just used a reasonably high cross price elasticity of -1.2. But interviewing did indicate that these chicken producers are very anxious to make even small cost savings given the pressure from many new entrants into broiler production and the falling prices for chicken meat. Their requirement for switching is that these changes do not have productivity effects.