

1 Review

2 A Glance at the Mozambican Dairy Research

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10 **Abstract:** The Mozambican dairy industry landscape is not well known because the research about
11 it presents numerous inconsistencies. These inconsistencies are possibly due to miscommunication
12 between scholars, entrepreneurs, the government and other actors, besides major events such as
13 the civil war and policy changes and overall lack of coordination. This study aimed to catalog and
14 relate the major studies and findings in the Mozambican dairy research, contextualize them
15 historically, analyze the implications and provide hints for future researchers. Dairy research
16 seemed intimately related to the industry's development, and it has been dependent on the
17 country's sociopolitical changes and opportunities. Social and economic studies are more
18 abundant, perhaps because the dairy industry is emerging, thriving to stand out in a very
19 competitive environment, but there are also studies in applied sciences, especially microbiology
20 and chemistry. There are promising directions to follow such as the improvement of herding
21 techniques (e.g. feeding, disease control), multidisciplinary synergies or exploration of traditional
22 dairy products such as masse. Also, it would be important for institutions to share their research
23 through electronic platforms, even the information published prior to the existence of the
24 worldwide web.

25 **Keywords:** Mozambique; dairy; research

26

27 1. Introduction

28 It seems even arguable if there is a dairy industry or not in Mozambique. On one side, Zvomuya
29 [1] described this sector as "virtually non-existent" and some authors agreed through a chain of
30 cross-references [2,3], while on the other hand Castel-Branco [4] classified it as an "emerging
31 agricultural industry". Whatever the point of view is, there are several smallholder dairy farms, at
32 least 8 milk-processing companies [1,3,5] throughout the country, several markets selling the
33 domestic milk [1,6] and perspectives to export dairy products [1]. Thus, there is a value chain on
34 which several people depend and it deserves some attention. Furthermore, there seems to be an
35 increasing interest in the matter.

36 Alberro [7] called for the need to produce more animal protein in tropical developing countries
37 almost 40 years ago but even now it has been difficult in Mozambique because the most productive
38 cows are not well adapted to tropical settings. Quisumbing, *et al.* [2] agreed and added that a 16-year
39 post-independence civil war also prevented the dairy industry to develop. Thus, it is necessary to
40 study how the milk production could be improved. The country has very little research about dairy
41 manufacturing and its industry [1,6]. A challenged body of multidisciplinary academic work have
42 been accompanying the thriving dairy sector, describing its status or seeking for solutions and
43 improvements [6,8].

44 There were some bursts of considerable research but they do not seem to be planned as
45 long-term projects. As result, the current knowledge is fragmented in contextualized pieces from
46 certain places and periods, sometimes inconsistent or even conflicting [3,8]. Future researchers will
47 need a concise catalog showing how each study on the Mozambican dairy manufacturing is located

48 within the *zeitgeist* considering the country's historical, social, economic and scientific intricacies.
 49 This article aims to provide a comprehensive view of the current dairy research in Mozambique,
 50 trying to explain how it took its shape, its impact on the current state of knowledge, and which
 51 directions could be taken in the near future.

52 The article will start by presenting the country's geographic features because there are several
 53 references to cities and provinces, and also to sociopolitical issues. Then, it will describe how the
 54 dairy industry evolved throughout the country's history, and finally describe how the research has
 55 been carried and how it contributed to the present knowledge on the Mozambican dairy
 56 manufacturing.

57 2. Geographic Features

58 The Republic of Mozambique (Figure 1) is a South-eastern African country bordering
 59 Mozambique Channel with a coastline of 2,470 km [9,10]. The geographic coordinates are 18°15' S
 60 and 35° 00' E [9]. The country is surrounded by Tanzania (north), Malawi and Zambia (northwest),
 61 Zimbabwe (west), Swaziland (south) and South Africa (southeast) [10]. The total area is 799,380 km²,
 62 being 786,380 km² of land and 13,000 km² of water [9]. The climate is tropical and subtropical humid
 63 [9,10] and it has fertile soils, especially in the northern mountainous areas near the Zambezi river
 64 [11].



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Figure 1. Mozambique. Source: Geographic Guide [12].

67 The total population is estimated to 23.9 million people [13]. According to United Nations
68 Children's Fund (UNICEF) [14] and [15], about 69% live in rural areas. Though it had one of the
69 African highest annual economic growth rates (6.8-7.6 %) in the last decade, Mozambique but a civil
70 war (1977-1992), natural calamities among other issues are the reasons why the country still depends
71 on 40% of foreign assistance for its annual budget [9,13,16]. The GDP is 12.9 billion US dollars and it
72 comes from agriculture (29.8%), industry (23%) and services (47%) [13,18]. The main exports are
73 cashew products (US\$ 21 million), prawn (US\$ 42 million) and manufactures (US\$ 34 million) [13,18]
74 but there are other commodities such as aluminium, electricity, tobacco, sugar, cotton and timber
75 [18,19].

76 The main export partners are Netherlands (36.9%), South Africa (14.6%), Portugal (3.4%) and
77 China (2.5%) [18]. The local cashew industry used to be the World leader, with 35-40% international
78 market share but it had a downsizing basically because of inefficiencies during a major economic
79 reform [20,21]. Yet, Große-Rüschkamp and Seelige [22] reported a growth from 0.5 to 3.25 million
80 tonnes from middle 1980s to 2007.

81 3. Historical context

82 It is necessary to have an idea about the evolution of the Mozambican sociopolitical context in
83 order to better visualize the research directions in the dairy industry. The country has undergone
84 several changes since the colonial era, independence, civil war, establishment of a democratic system
85 and harmonization with the Millennium Declaration [23,24]. These changes led to economic
86 readjustments and certainly affected all sectors of production, including research and development.

87 The Portuguese effectively occupied Mozambique soon after the Berlin Conference (1884–85)
88 and the defeat of the Emperor Ngungunhane (1895). Since then, they controlled the production.
89 According to Raikes [25], the dairy industry grew considerably just before the independence
90 (1950-65) because the major cities were growing and attracting people from the metropolis,
91 demanding "high-income foodstuffs" such as wheat flour, meat and dairy. A network of supply
92 chains developed rapidly, enhanced by the participation of South African farmers and firms.
93 However, the war of independence (1964-74) and its aftermath certainly destabilized the sector.

94 The post-colonial Government (1975-89) discouraged the private sector because the country
95 was under a Marxist-Leninist orientation with one party, and all major decisions were under central
96 rule. Even education and research should comply with the country's priorities, with little flexibility
97 to develop. For instance, the Government ceased some departments of the only university at that
98 time (Eduardo Mondlane). This setting certainly discouraged research in any field and international
99 collaborations, especially from countries under a different regime.

100 In 1987, Mozambique changed its priorities to get support from the International Monetary
101 Fund (IMF) and the regime changed to democratic. The resulting project was designated Economic
102 Rehabilitation Program, under which the Government allowed citizens to purchase most of its
103 properties and stimulated entrepreneurship [26,27]. According to Vernooij, *et al.* [3], most dairy
104 farms were privatized between 1994 and 1997. The state also developed strategies to attract foreign
105 investment and collaborations such as transference of technology, capacity building and assistance.
106 The academia also expanded, private schools and research centers opened, providing means for
107 some research to take place. The situation became even more favorable after the peace treaty, signed
108 on October 4th, 1992. Yet, there is very little information on the Mozambican dairy industry during
109 1990s. Perhaps the most relevant is the overview by Faftine [28] on the use of cows in smallholder
110 farming systems presented in Ethiopia, 1995. This shortage of information is possibly because: the
111 governance was under transition, drawing most attention to production instead of research; priority
112 areas were fisheries and cash crops such as cassava, maize and peanuts; there was no investment for
113 the dairy industry; there was little technical or academic expertise and technology related to dairy
114 production; the new open market promoted competition, and assessments were made between
115 institutions under professional secrecy.

116 The new millennium came with a new worldwide sociopolitical framework, partially because
117 of the Millennium Development Goals (MDG), and now the Sustainable Development Goals (SDG)

118 [24]. As response, Mozambique developed the Plan of Activities to Reduce Poverty (PARP) [29],
119 facilitating the introduction or expansion of projects able to address the goals, especially the combat
120 against poverty, hunger and disease. There were also strong incentives for education. A real locally
121 based dairy industry started to take shape in this era: South African branch of Parmalat SpA opened
122 a facility in Maputo Province [30], Brendon Evans inaugurated Gouda Gold in Manica province [1],
123 Land O' Lakes start collaborating with dairy farm smallholders [6] and several dairy plants took off
124 throughout the country [3]. Some research accompanied the establishment of such firms, most
125 related to economic viability. Furthermore, dairy research is likely to become more active in
126 Mozambique because there is an increasing number of research centers, universities and polytechnic
127 institutes with food science programs [31].

128 4. Early Studies

129 There was an extensive research on the Mozambican dairy production during the colonial era.
130 Pereira Martinho [32] presented the results in his book called Some Aspects of the Livestock Problem
131 in Mozambique, with details such as the cow types, their productivity and distribution throughout
132 the territory, owners' ethnicities and how they treated the cows. According to him, cows were less
133 abundant in Mozambique compared to the surrounding territories, most farms were located at the
134 southern area, and the native cows were not as productive as Friesians. Achá, *et al.* [33] say this is
135 due to abundance of tse-tse flies (*Glossina spp.*). Landim, the preferred local type, was crossed with
136 European breeds, originating considerably productive cows. For instance, Landim x Friesian was
137 able to produce 3000 liters in 300 days in the 4th or 5th lactation, and Landim x Jersey could produce
138 2000 liters for a similar period.

139 Some post-colonial studies are available in David Lubin Memorial Library of the Food and
140 Health Organization of the United Nations [34]. They covered different aspects of dairy production
141 and how to improve it. The readily accessible literature has very little information on how these
142 studies were conducted and even their results. But it is possible to grasp the state of research and
143 where it was heading.

144 Alberro [7] kick-started the post-colonial research in 1980 by comparing the productivity
145 between Holstein, Dutch and Africander x Friesian heifers. The two former started producing milk
146 earlier, and yielded more for a longer period than Africander. The following year he described the
147 management, feeding and behavior of Friesian dairy herds in the coastal belt of Mozambique [35]. In
148 1984, a group of scientists presented studies on reproduction of Mozambican dairy cattle in the 10th
149 International Congress on Animal Reproduction and Artificial Insemination, Illinois, United States.
150 Diaz talked about abortion and death [36], Rocha and Diaz about artificial insemination [37], and
151 Thompson about microbial flora in the cervical mucus of dairy cows. The same year, Raikes [25]
152 mentioned dairy production in his article on how policies are affecting the food industry in
153 Mozambique.

154 Another important study was published by Alinder and Ingevall [38] in 1985. After a soil
155 survey in the country's southern region, they conceived an irrigation scheme for a dairy farm. The
156 same year Maputo City hosted the Seminar on Animal Production, where de Vries [39] and Diaz [40]
157 presented their progress on dairy research. The former proposed the introduction of rice straw in
158 dairy cattle's diet and the latter suggested some improvements for the dairy cattle production in
159 Mozambique.

160 The studies mentioned in this section were focused on the cattle's health rather than dairy
161 quality or safety. This was possibly because the country was still attempting to re-establish the
162 industry after the Portuguese left with key manufacturing resources. Dairy production relied on
163 large farms with exotic animals, modern equipment, special feedstuffs, drugs, and a timely arrival of
164 supplies and services [25]. Furthermore, the country was struggling to implement post-colonial
165 policies and under a civil war from 1977 to 1992 [2,41,42].

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167

168 **5. Recent Studies**

169 Among recent documents worth mentioning about dairy production in Mozambique, the ones
 170 on Table 1 are enough to cover the most relevant information. Other studies are either related or do
 171 not seem as pertinent. They will be mentioned when or if necessary. The major documents on dairy
 172 food in Mozambique are mostly journal articles but there are also magazine feature articles,
 173 proceedings, and academic dissertations, project reports, among others. Most cover agribusiness,
 174 economics or social sciences but few also feature natural sciences or multidisciplinary studies. The
 175 frequent focus on farm management is perhaps due to the recent strong incentive to
 176 entrepreneurship in Mozambique, especially for agriculture [43,44]. Former President Armando
 177 Guebuza introduced a fund to develop small and medium-sized enterprises in the countryside to
 178 stimulate development and decentralize the economy [45], accessible for any citizen who presented
 179 a mid-long term sustainable plan [46,47]. The following discussion will first focus on economics and
 180 the social studies, and then natural sciences.

181 Table 1. Major recent publications describing dairy production in Mozambique.

Year	Author	Document type	Subject	Focus
1995	Faftine [28]	Proceeding	Economics	Farm management
2003	Castel-Branco [4]	Journal article	Economics	Industry analysis
2004	Achá, <i>et al.</i> [33]	Journal article	Microbiology	Animal health
2008	Slabbert [30]	Magazine article	Agribusiness	Interview (entrepreneur)
2009	Zvomuya [1]	Magazine article	Agribusiness	Interview (entrepreneur)
2011	Rungo [48]	Dissertation	Chemistry	Milk quality
2012	Zucula [49]	Dissertation	Chemistry	Milk quality
2013	Schutte [50]	Dissertation	Microbiology	Milk quality
2014	dos Anjos, <i>et al.</i> [51]	Journal article	Animal production	Cassava as cow feed
2015	Ouana [52]	Dissertation	Chemistry	Butter quality
	Johnson, <i>et al.</i> [53]	Journal article	Gender studies	Farm management
2016	Chagunda, <i>et al.</i> [54]	Journal article	Agribusiness	Farm management
	Vernooij, <i>et al.</i> [3]	Consultancy report	Agribusiness	Industry analysis
2018	Mahomed and Nunes [6]	Journal article	Agribusiness	Business plan

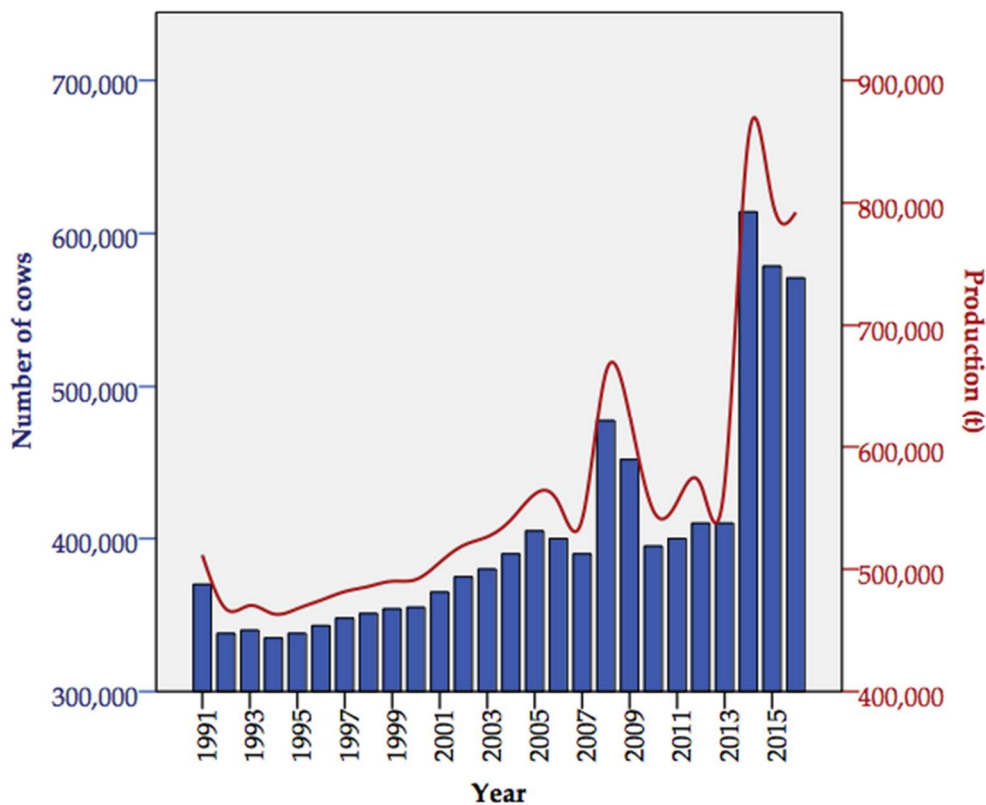
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183 *5.1. Economic and social studies*

184 Dr. Olga Faftine [28] can be considered the first scholarly authority describing the dairy
 185 industry after the peace treaty (1992) and establishment of the first democratic Government (1994).
 186 In summary, she confirmed the predominance of cattle in the country's south and center and
 187 provided a glance on the changes during the civil war. According to her, the number of cows
 188 declined from one million to around 200,000 in 1992 and milk production from 10 million to 1
 189 million liters per year. However, it is reasonable not to consider Faftine's analysis as part as the most
 190 recent dairy research because he published his document when the Government was following the
 191 Program for Economic Rehabilitation rather than the current Plan for Poverty Reduction.
 192 Furthermore, the flood in 2000 affected several farmers throughout the country's south and center
 193 [55], many lost their goods and had to be reallocated, affecting the area's agricultural landscape. Yet,
 194 the country kept most agricultural policies and several aspects he mentioned still apply [1] or can
 195 facilitate the understanding of the current situation.

196 The United Nations (UN) [56] has records on the number of dairy cattle and milk production in
 197 Mozambique since 1991 (Figure 2). According to the database, the number of dairy cows seems to

198 have increased from perhaps lower than 300,000 head to almost 600,000, and there were two leaps of
 199 a considerable proliferation: 2008 and 2014. Raimundo Diomba, Manica provincial governor, also
 200 stated this trend when he said that milk market was expanding as response to consumer demand [1].
 201 However, UN's values seem too high for the values reported by Faftine [28] and Vernooij, *et al.* [3]
 202 and low for Zvomuya's [1]. For instance, Vernooij, *et al.* [3] said the annual milk production is 82,000
 203 metric tonnes annually, according to the Emerging Markets Analysts Report published in 2014, but
 204 the author recognizes that "exact figures on milk production in Mozambique are scarce and often
 205 conflicting". The differences are possibly because information technologies have been improving
 206 and facilitating services such as census and statistics, and UN regularly updates its database.
 207 Furthermore, part of the milk produced locally is sold informally [3], and part of it is potentially
 208 underreported.



209

210 Figure 2. Number of cattle and milk production in Mozambique from 1991 to 2016. The bars
 211 represent the number of head and the red line represents the variation in the quantity of milk. Note: t
 212 – metric tonnes. Based on UN [56].

213 Milk production showed a very similar trend to the number of head, increasing from around
 214 500,000 to 800,000 tonnes. It suggests that yield did not change considerably. Indeed, a
 215 Kolmogorov-Smirnov one-sample test of the yield provided by UN [56] showed not significant
 216 variation over time ($p = 0.96$), with the confidence interval 13846–59 hectoliters per cow annually. In
 217 this case, both Faftine [28] and Zvomuya's [1] presented "humbler" statistics, with values below
 218 80,000 tonnes. The quantity of milk produced in Mozambique seems reasonable if compared to other
 219 african countries. For instance, while Kenya and Ethiopia show records of over a million tonnes,
 220 Madagascar, Uganda and Tanzania present values close to Mozambique's [57]. Yet, Zvomuya's [1]
 221 said milk consumption is very low even for the quantity produced. According to the author, the
 222 average Mozambican consume only 5.7 liters of milk annually, and it declined from 9.1 liter in 1990.
 223 For the sake of comparison, he said the world average is 79 liters per capita.

224 Ten years later, Castel-Branco [4] published the following relevant article considering that
 225 Faftine actually described facts up to 1992. He wrote about Mozambican economic growth in

226 general, mentioning the dairy production in few instances as example. He classified dairy
 227 manufacturing as an emerging agricultural industry because it heavily relies on imported products
 228 in late stages of processing. Indeed, two interviews published in the Dairy Mail Africa subsidize
 229 Castel-Branco's line of thought. Slabbert [30] interviewed Parmalat's chief executive officer (Theo
 230 Hendrickse), and identified this company as the leading dairy factory in Mozambique. The author
 231 said said that the country's branch has been considerably profitable, even when Parmalat was facing
 232 a crisis worldwide. But Zvomuya [1] said the company does not produce or refine raw milk, instead
 233 Parmalat imports all inputs including packaging material and powdered milk and sells as
 234 ultra-high-temperature (UHT) processed milk. Mahomed and Nunes [6] identified Gouda Gold and
 235 Land O' Lakes as the largest dairy manufacturers relying solely on local raw material and delivering
 236 finished products. Table 2 shows these and other major dairy producers in Mozambique.

237 Table 2. The major dairy manufacturers in Mozambique and their product features.

Province	Company name	Dairy input	Main products
Maputo	Parmalat	Imported	Fresh milk, cheese
	Protal	Imported	Condensed milk, cheese
Sofala	Copolate	Local	Fresh milk
	DanMoz	Local	Fresh milk
Manica	AgroMaco	Local	Fresh milk
	Gouda Gold	Local	Fresh milk, cheese
	Land O' Lakes	Local	Fresh milk
Nampula	Rafza Rostongy	Local	Fresh milk

Adapted from Vernooij, *et al.* [3], Mahomed and Nunes [6], and Zvomuya [1].

238 The processing plants from Maputo import their material, partially processed, focusing their
 239 activity more on the final steps, packaging and branding [1,58]. Assuming that cattle farms are more
 240 abundant in the country's south and center [28,33], it would be reasonable to expect the companies
 241 of Maputo to use local raw materials, as it is the Mozambique's most southern province. However,
 242 the area is strategically located near South Africa, the Maputo-Witbank road facilitates circulation
 243 between both countries [59], South Africa has relatively low cost high quality milk [60], more stable
 244 and predictable price fluctuations [61,62], and the local supply might not be enough for demands of
 245 Parmalat and Protal. Furthermore, historical reasons should be also considered. Parmalat was
 246 introduced in Maputo through the South African subsidiary [1,30] and it certainly had already an
 247 established supply chain, entering Mozambique especially to sell the milk and derivatives. Protal
 248 also commenced as an import-export firm for condensed milk and processed cheese [58].

249 Fidelis Zvomuya [1] interviewed the founder of Gouda Gold, Brendon Evans, providing
 250 valuable insights about the Mozambican dairy industry in 2009. The entrepreneur described the
 251 industry as "virtually non-existing" until he went to Mozambique as a refugee from Zimbabwe's
 252 regime in 2002, and established in Manica Province with only 20 cows from the originally over 200.
 253 His radical view perhaps refers to the absence of coordinated enterprises covering the entire dairy
 254 production chain consistently responding to market's demands. Evans was pioneer in this sense by
 255 opening the first cheese-manufacturing factory in Mozambique, inaugurated in May 2007 and built
 256 to meet international and European Union standards, so as the Guidelines of the International Labor
 257 Organization (ILO). The company has Dutch partners such as Scherjon Dairy Equipment and
 258 Advance Consulting Haarl, and the Private Sector Investment Program (PSI), formerly known as
 259 PSOM. These organizations provided assistance, equipment and loans to support Gouda Gold.

260 Land O' Lakes managed an initiative called Manica Smallholder Dairy Development Program
 261 (MSDDP) from 2008 to 2012 to rebuild the Mozambican dairy industry and increase smallholder
 262 farmers' income as milk producers. The cooperative claims to have doubled the number of dairy
 263 cows and tripled the volume of milk produced in Manica [63]. The company has plenty of
 264 information on the program at its website [64] but there also are some scholarly documents on the
 265 topic. For instance, Nancy Johnson *et al.* published two papers [2,53], both focused on the female

266 contribution for the success of the initiative. According to them and Zvomuya [1], the United States
267 Department of Agriculture awarded Land O' Lakes a Food for Progress Project grant to support
268 dairy farmers from Manica Province. The company used USD \$6 million to provide 400 dairy cows
269 to local farmers and to finance artificial insemination. After a survey in 125 households in 2011 and
270 150 in 2012, Johnson *et al.* [53] found that: men owned most assets such as lands and cows but they
271 frequently shared with their wives, still keeping the control over the revenues; the participation in
272 the program increased the farmers' income and access to nutritious food, regardless if the assets
273 were managed by men or women; men tended to reinvest the revenue in assets to improve the
274 business while women spent most of it improving the household quality of life. In any case, dairy
275 business seemed to increase farmers' income and promote the participation of women in the labor
276 force, thus empowering them.

277 In 2016, Chagunda, *et al.* [54] published another study related with MSDDP, though this was
278 about the initiative in Mozambique and four other countries from Sub-Saharan Africa: Kenya,
279 Tanzania, Malawi and Zambia. They shared valuable insights about Mozambique. For instance, they
280 described the average land size per smallholder (3.88 ha), the use cassava roots and leaves to feed
281 cattle, and the cross-breeding between the indigenous zebu cattle and Holstein-Friesian.

282 Vernooij, *et al.* [3] published a report of livestock development in the Zambezi valley, also in
283 2016. It incorporates findings by Vernooij and Wilschut [8], available since the previous year at the
284 Wageningen Centre for Development Innovation database. It is arguably the most detailed and
285 updated Mozambican dairy value chain analysis to date and a good introductory reference for
286 future researchers on the topic. They identified four processing plants (already described in Table 2)
287 , described the daily production as 2,000 litres in Chimoio and 1,100 litres in Beira. They described
288 some constraints for farmers such as limited market access, low productivity because of limited
289 husbandry skills, lack of nutritious feed or suitable breeds for milk production, reproduction issues
290 and disease, besides the fact that the most productive dairy cows are adapted to temperate climates
291 [7,35]. Furthermore, Vernooij, *et al.* [3]:

- 292 • Identified the main actors in the value chain: the Government, a dairy cooperative in the city of
293 Beira, non-governmental organizations (NGOs) and smallholders;
- 294 • Described the production in quantity and volume per province, some initiatives including
295 Manica Smallholder Dairy Development Program;
- 296 • Dairy cow feeding and reproduction;
- 297 • Analysis of strengths and weaknesses.

298 Mahomed and Nunes [6] published in 2018 an analysis of viability for the establishment of a
299 new dairy factory in Mozambique. Their article summarizes Mahomed's dissertation [5] published
300 in 2017. They focused on Maputo, Beira and Nampula because these are the country's major cities
301 and the study was market-oriented. They provided unique insights about the consumer's
302 point-of-view, discussing about perception on the price per liter, dairy purchase habits and patterns,
303 milk substitutes, and a projection on dairy demand. Considering these variables, the market seems
304 viable for the implantation a dairy manufacturer. This result subsidizes what the governor of Manica
305 said [1], though Mahomed's studies were in different areas of the country. Moreover, their article is
306 the only about the Mozambican dairy industry including butter among the products. This is a very
307 important point because butter is arguably perceived as the most popular dairy product in
308 Mozambique [52,65], eaten by virtually the entire population as part of the breakfast, accompanying
309 bread or boiled cassava roots and black tea [65]. Most authors did not include butter possibly
310 because most butter is imported from South Africa and many people consume margarine as a
311 substitute because of its lower price, and margarines might have very little dairy among its
312 ingredients [66].

313 Yet, value chain analysis so far mentioned condensed milk, but the local population consumes it
314 frequently, uses it for baking and knows very well the manufacturers. The most widely known
315 manufacturer is Protal, the country's major dairy company before the arrival of Parmalat [58]. The
316 enterprise predates independence and remained active through all sociopolitical changes. It
317 commenced in 1956 when the industrialist Jaime Cardoso sold his Hotel in Beira and set up a dairy

318 import-export company in Lourenço Marques (now Maputo City). He imported condensed milk,
319 competing directly with the Nestlé brand Cruz Azul. Later, his firm merged with Protal, founded in
320 1968 [49]. The company has approximately 70 workers, most engaged in production and packaging.
321 Their main products are condensed milk under the brands "Protal" and "Blue Crown", and Belarosa
322 processed cheese. This story conflicts with Zvomuya's [9] claims about Gouda Gold as the first
323 cheese manufacturer, but maybe the author meant "first primary producer", as Protal imports its
324 raw materials. The only research on Protal was published in two dissertations of chemical studies
325 [1,50] and a biography of Carlos Cardoso [58], a deceased influential journalist. The dissertations
326 will be examined in the section 5.2.

327 So far, the social and economics Mozambican dairy research seems to be increasingly intense as
328 the sector also develops, especially the smallholders. Most research was associated with Manica
329 Smallholder Dairy Development Program but new initiatives will possibly trigger further research.
330 For instance, the papers published by Faftine [28] and Castel-Branco [4] were not really focused on
331 the dairy industry and mentioned it as an example to illustrate their particular arguments towards
332 concerns non-related to dairy, while latest studies [6,8] were assessments of dairy value chain in the
333 country. The article by Mahomed and da Silva Nunes [6] implied the intention to install a dairy
334 factory in Mozambique.

335 5.2. Natural and Applied Sciences

336 Research on natural or applied sciences seemed frequently related to the social and economic
337 counterparts, sometimes as a component of the others. It happened through synergies, such as cases
338 in which companies and research institutions joined efforts to analyze dairy production but each
339 organization acted according to its own expertise or interests. For instance, Eduardo Mondlane
340 University (UEM) collaborated with other organizations such as University of Zimbabwe [51],
341 Wageningen University and Research [3], Future Farming Systems Group and other institutions
342 [54]. Even within UEM different faculties have collaborated, exploring different aspects of dairy
343 production. Thus, there will be some references to the works described in the previous sections. The
344 studies will be presented according to subjects rather than a chronological order for the sake of
345 thematic coherence, starting by the biological studies and then covering the chemical analyses.

346 This section will cover first the study by dos Anjos, *et al.* [51] in 2014. They analyzed the
347 potential of cassava plant to be integrated in dairy cattle diet as an affordable energy source, as this
348 practice had been introduced in some tropical countries. Feeding trials using cassava hay showed a
349 dry matter intake (DMI) of 3.2% of the body weight (BW) and digestibility of 71%. Other benefits
350 were low feeding cost if compared to maize-based feed, anthelmintic and therapeutic effect due to
351 the presence of tannins. This study is related to the one by Chagunda, *et al.* [54] mentioned in the
352 section 5.1 about how to improve the productivity in dairy farms. These authors mentioned many
353 other examples supporting the use of cassava as a viable alternative to lower dairy production cost.

354 Ten years earlier, Achá, *et al.* [33] actually published the first major post-war scientific study on
355 dairy farming. They screened calves 1241 for diarrhea, aiming to analyze the prevalence and
356 etiology. The calves belonged to 8 farms throughout the country. The prevalence was low (5%) but
357 relatively high in two farms (13% and 21%). Among the calves with diarrhea, and 11% were positive
358 to *Campylobacter jejuni*, 2% for *Salmonella spp.* and 40% to K99 adhesin, indicating the presence of
359 enterotoxigenic *Escherichia coli* (ETEC). Some sources described a different pattern of prevalence
360 [67,68] at which ETEC is more frequent, followed by *Salmonella spp.* and less frequently *C. jejuni* and
361 *Clostridium perfringens*. Achá, *et al.* [33] said the unusual abundance of *Campylobacter* might have been
362 related to outbreaks in some farms. This seems to be a promising research direction. For instance, the
363 authors could have searched for the true cause of the differences with other studies; they could have
364 included other microorganisms or parasites, analyze the impact of disease on the farms'
365 productivity or much more. However, this study apparently had no follow-up.

366 In 2013, Schutte [50] published another microbiological study as a masters dissertation at the
367 University of Stellenbosch, South Africa. The author's focus was on the microbial flora of
368 traditionally fermented milks in Sub-Saharan Africa, including a drink called *masse* from

369 Mozambique. *Masse* is a beverage prepared through spontaneous fermentation of raw milk. It has a
370 sour taste and a considerably dense consistency, similar to yogurt. Schutte [50] detected *Leuconostoc*
371 in 68% of the samples (average 2000 cfu/ml). The author did not study the safety as the interest
372 seemed turned to organoleptic properties. *Masse* and other African traditional fermented milks have
373 more diversity in microorganisms when compared to commercial fermented milks, meaning that
374 they possess very rich floras with potential to provide new properties to foods commercially
375 available. This was a very innovative and necessary line research, though it is advanced for an
376 industry still thriving to exist in Mozambique. Yet, as it is a local traditional drink, people already
377 have the know-how to produce it. Furthermore, the country could gain some competitive advantage
378 by legally protecting as traditional knowledge or under geographical indication through the
379 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) [69].

380 Finally, there are studies on dairy chemical properties, all licentiate dissertations from the
381 Faculty of Sciences, Eduardo Mondlane University. The first was published by Rungo [48], who
382 developed a set of protocols for experiments on chemical engineering. His dissertation catalogs
383 major processes to analyze the quality of condensed milk, such as fat extraction and quantification of
384 sucrose. This study did not contain any novelty because it was not meant to, but it is among the few
385 scholarly documents mentioning Protal as a major dairy company in Maputo City. However, it was
386 not merely focused on dairy production as the author interviewed and reviewed processes from
387 several chemical industries. Zucula [49] was the only one who specifically studied condensed milk
388 processing by Protal, providing the only Mozambican scholarly description published to date about
389 dairy's full analytical process for quality control and assurance, including the chemical,
390 microbiological and organoleptic components. Ouana [52] evaluated the quality of Tulip butter and
391 two margarine brands (Rama and Flora), all imported but widely consumed locally. According to
392 the author, the values were within the Codex Alimentarius limits for acidity, iodine, fat, volatile
393 substances and impurities insoluble in ether. A unique aspect of this study is the attention to butter
394 and even margarine, perhaps the most important but "underrated" dairy products in Mozambican
395 academic circles, possibly because they bear little resemblance to the raw material. Curiously, yogurt
396 also seems underrated.

397 6. Conclusions and recommendations

398 It was an exaggeration to say that there is virtually no dairy industry in Mozambique.
399 Castel-Branco gave perhaps the most accurate description by saying that it is an emerging
400 agricultural industry, lacking some elements to be fully established and using mostly local input.
401 There is a market and value chain, modestly defined. What the Mozambican dairy industry needs is
402 proper leadership and collaboration to face numerous challenges including "almost unfair" foreign
403 competitors. One successful example was the Manica Smallholder Dairy Development Program. It
404 would not have been possible without the investment for sure, but part of its success was certainly
405 due to a well-coordinated plan of activities and allocation of resources. Furthermore, the
406 government should issue and enforce policies encouraging large companies to prioritize the milk
407 locally produced over imports, and build infrastructures to collect milk from the smallholder dairy
408 farmers.

409 Regarding dairy research, it is emerging likewise. Scholars might be facing difficulties getting
410 funding because priorities are turned toward cash crops and other food industries more developed
411 such as fisheries or poultry. Yet, there seems to be increasing production interest on dairy in
412 Mozambique, together with the incentives for entrepreneurship and a larger number of research
413 facilities, opportunities and experts. Hopefully, each case of success will spread optimism among
414 actual and potential stakeholders and maybe the country will be able to better deal with the external
415 competition.

416 There are also different research directions, all promising. Perhaps the most important is not to
417 stop any project in the middle or stimulate follow-ups. The academic departments or research
418 centers should design projects with mid or long term impact, and also collaborate more by creating
419 multidisciplinary synergies able to study the dairy production from different perspectives. There are

420 a few industry analyses and studies on applied sciences. Academia and research centers should
 421 encourage students, young researchers and entrepreneurs to pursue dairy industry quests and bring
 422 solutions to each challenge. For instance, it would be advantageous if the country could explore the
 423 potential of traditional dairy products and start an all-new industry, gaining competitive advantage.

424 Above all, there are probably various documents like the ones in the Library of the Food and
 425 Agricultural Organization, existing only in the physical format. This is probably because they were
 426 issued prior to the expansion of electronic resources such as the worldwide web. These documents
 427 would be an asset to researchers if available online. Even if such documents seem outdated they can
 428 bring unparalleled insights, able to provide a more accurate picture about the dairy production
 429 landscape in Mozambique.

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