

Use, Production and Existence of Local *Artemia* Resources in Uganda and Africa: A Review

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Abstract

This study was aimed at reporting the existing *Artemia* habitats, its use and production in Uganda and Africa as a continent. In light of the great importance of *Artemia* as a starter feed in the aquaculture industry, its current shortage in supply, the need for commercial exploitation of local *Artemia* resources and development of new *Artemia* resources. Over 50 peer reviewed journal articles were reviewed to provide an understanding of the current status of *Artemia* use, production and existence of local existing *Artemia* resources in Uganda and Africa as continent. The study revealed neither local occurring *Artemia* resources nor commercial *Artemia* production is currently existent in Uganda, with its use mainly restricted to a few existing commercial hatcheries. Generally *Artemia* use in Africa is mainly restricted to the few commercial fish hatcheries. Literatures points to North African countries boarding the Mediterranean to be leading in the number of *Artemia* sites and production in Africa.

Keywords: *Artemia* habitats, Hypersaline lakes, Aquaculture

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Introduction

Artemia are typical inhabitants of hypersaline environments belonging to anostracan micro-crustaceans of genus *Artemia* (Gajardo, Parraguéz et al. 2001 ; Kaiser, Gordon et al. 2006; Ogello, Kembanya et al. 2014). Although Schlosser is reported by scientific manuscripts to have the first description of *Artemia* in salt pans of Lymington, Hampshire (England) in 1755 (Kuenen. and Becking. 1938; Asem. 2008), *Artemia* records in lake Urmia dates back to 982 by unknown Iranian author (Asem. 2008; Ben Naceur, Jenhani et al. 2012; Kara and Amarouyache 2012). Mankind has known *Artemia* for so many years with native Amerindian and Lybians reported to have been using *Artemia* as food so many years ago (Asem. 2008). *Artemia* is a primitive arthropod having a segmented body, with leaf-like appendages known as thoracopods. Adult *Artemia* is reported to vary in length between 8 to 10mm and 10 to 12mms for males and females respectively. Both males and females are reported to have an approximate width of about 4mm (FAO 2015). This genus is reported to have bisexual and parthenogenetic populations that are similar morphologically and biometrically (Triantaphyllidis, Abatzopoulos et al. 1998; Nasser, Peter et al. 2009; MUÑOZ and PACIOS 2010; Castro-Mejía, Castro-Barrera et al. 2011). Bisexual *Artemia* populations include *Artemia franciscana* and *Artemia persimilis* which have been classified as the new world *Artemia* populations and are usually diploids while their parthenogenetic relatives (*A. salina*, *A. sinica*, *A. urmiana* and *A. tibetiana*) which are polyploids are referred to as the Old World populations (Triantaphyllidis, Criel et al. 1997; Baxevanis, Kappas et al. 2006; Maccari, Amat et al. 2013). Bisexual populations are found on all continents except the Antarctica while parthenogenetic populations are endemic to Europe, Asia and Australia (Triantaphyllidis, Criel et al. 1997). Reproduction in *Artemia* is reported to be by either ovoviviparity where eggs hatch into live young ones within the body before being released or oviparity where metabolism and embryonic development in the embryo are arrested to form diapausing cysts (Nasser, Peter et al. 2009; Sugumar 2010). The later has been reported as a crucial strategy for surviving unfavorable environment conditions, where the cysts remain in this stage of arrested

metabolism and remain viable for many years (Papeschi., Alba et al. 2008). Different conditions have been reported to be responsible for the switch between Ovoviviparity and oviparity.

Artemia has been reported to have a wide geographical distribution (Kaiser, Gordon et al. 2006; Ben Naceur, Jenhani et al. 2009), occurring in all continents with the exception of the Antarctica (Papeschi., Alba et al. 2008; Ben Naceur, Jenhani et al. 2009; Ben Naceur, Jenhani et al. 2012). Over 600 habitats of *Artemia* populations have been reported world-wide in natural salt water bodies and man-made salterns (Ogello, Kembenya et al. 2014; Van Stappen 2002). The distribution of these populations are reportedly reflected in paths of some migratory birds as well as intentional inoculations by man for commercial purposes (Nasser, Peter et al. 2009; Munoz, Green et al. 2013). It is adapted to survive and live under hypersaline conditions in salt lakes, ponds, coastal salt lagoons, pans and solar saltworks (Kaiser, Gordon et al. 2006; Ben Naceur, Jenhani et al. 2009; Ogello, Kembenya et al. 2014). They have been reportedly found in athalassohaline and thalassohaline environments with salinities as high as 340g/l (Nasser, Peter et al. 2009; Ogello, Kembenya et al. 2014). *Artemia* is reported to withstand stressful conditions imposed by hypersaline environments such as fluctuating temperatures, salinity, and ionic composition (Gajardo and Beardmore 2012; Ogello, Kembenya et al. 2014). Being highly osmotolerant (Ogello, Kembenya et al. 2014) and the ability to have an interchangeable life cycle which can switch between diapausing cysts and live nauplii depending on environmental conditions are some of the key adaptations reported to enable *Artemia* to withstand these stressful conditions (Kaiser, Gordon et al. 2006; Ben Naceur, Jenhani et al. 2009; Gajardo and Beardmore 2012). A number of literatures have pointed to salinity as the main environmental parameters affecting the distribution of *Artemia* (Vanhaecke, Tackaert et al. 1987; Kaiser, Gordon et al. 2006), with other like temperature, light intensity, food availability more responsible for the numbers and densities of *Artemia* populations (Vanhaecke, Tackaert et al. 1987).

Artemia is reported to be among the most widely used live feed for larviculture of fish and shell fish (Sorgeloos, Lavens et al. 1991; Philips 2010), with over 2000 metric tons of dry *Artemia* cysts produced and marketed annually world-wide (FAO 1996; Triantaphyllidis, Abatzopoulos et al. 1996; Ogello, Kembenya et al. 2014). Despite man having known *Artemia* for centuries, its use as food for larvae in the aquaculture industry began only in the 1930s when it was discovered to be nutritional rich for new hatched larvae (Bengtson, Leger et al. 1991; FAO 1996; Ogello, Kembenya et al. 2014). Since then *Artemia* was mainly collected from natural saline lakes and coastal salt works. As a result of the rapid expansion of the aquaculture production more especially in 1970's, the demand for *Artemia* exponentially increased to exceed production (FAO 1996; Sorgeloos, Dhert et al. 2001). Since then limited supply of *Artemia* has become a big impediment to the expansion of the aquaculture (Sorgeloos, Lavens et al. 1991; FAO 1996; Coutteau and Sorgeloos 1997; Maung, Nyi Bu et al. 2008), with many countries importing *Artemia* at prices ranging between US\$ 50 to 100 per kg (Jaccarini and Martens 1990; Bengtson, Leger et al. 1991). Annually *Artemia* production has been reported to fluctuate hence affecting *Artemia* market prices as well as raising hatchery production costs (Maung, Nyi Bu et al. 2008; Schwartz 2008).

Rotifers and *Artemia* are among the most used extensively used zooplanktons for larval rearing both in marine and freshwater aquaculture (Bengtson, Leger et al. 1991; Akbary, Hosseini et al. 2011; Ramesh, Dube et al. 2014). Availability as an off-the-shelf feed in form of dormant cysts is one of the key advantages of *Artemia* over other live feeds (Leger, Bengtson et al. 1987; Akbary, Hosseini et al. 2011). *Artemia* is hardy, ease to hatch (Tarekegn 2015), tolerant to unfavorable environmental changes, with a wide size range and different physical forms (Leger, Bengtson et al. 1987). *Artemia* if well packaged can stay viable for so many years (Bengtson, Leger et al. 1991; Ogello, Kembenya et al. 2014). All these render it more versatile and preferable in comparison to other live feeds. Other competitive advantages of *Artemia* use are the good nutritional value for fish larvae and the easy improvement in its nutritional value through enrichment techniques (Akbary, Hosseini et al. 2011). Through bioencapsulation *Artemia* has also been used as a route for transferring essential nutrients like Ascorbic acid (Immanuel, Citarasu et al. 2007; Akbary, Hosseini et al. 2011), probiotics (Arndt and Wagner 2007; Seenivasan, Bhavan et al. 2012), spawning hormone (Ogello, Kembenya et al. 2014), medication like anti-biotics (Nkambo, Bugenyi et al. 2015) and other feed supplements like Eicosapentaenoic acid (EPA) and docosahexanoic acid (DHA) to the fish (Han, Geurden et al. 2000). Ascorbic acids are necessary in the synthesis of collagen required in formation of connective tissue and bone matrix (Dabrowski and Blom 1994). *Artemia* production in salt ponds has also been documented to play a vital role in controlling algal blooms and thereby improving the salt crystallization process as well as leading to better salt quality (Ogello, Kembenya et al. 2014). *Artemia* is currently one of the model organisms which have been put to use in a number of environmental eco-toxicology, evolutionary and genetic studies (Baxevanis, Kappas et al. 2006; Ben Naceur, Jenhani et al. 2008; MUÑOZ and PACIOS 2010; Ogello, Kembenya et al. 2014).

Despite all the cited *Artemia* uses above and there being no single artificial diet that can be used as a completely substitute for *Artemia* in hatcheries (Ben Naceur, Jenhani et al. 2008) which makes it remain a must have feed in many hatcheries all over the world (Ogello, Kembenya et al. 2014), very little is known about its use, production and occurrence in Uganda and Africa as a continent. In this study potential *Artemia* sites in Uganda were visited and existing literature reviewed with an aim of investigating the existing information on the use,

production and occurrence of *Artemia* in Uganda and Africa.

Materials and Methods

In this study over fifty (50) journal articles were reviewed for data and information about use, production and existence of local *Artemia* resources in Uganda and Africa.

Discussion and Results

From this study, it was found out that literature highlighting the use of *Artemia* in Ugandan hatcheries and in African hatcheries at large is very scarce. This could be attributed to commercial hatcheries being very few in Uganda with the majority of them still dependant on un-standardised technologies and practices (Mwanja, Rutaisire et al. 2015). Uganda is reported to have only three commercial private hatcheries with the rest being small scale hatcheries. Only 31% of the Ugandan hatchery operators have been reported to use *Artemia* alone in weaning fish larvae (Mwanja, Rutaisire et al. 2015). This small percentage of farmers using *Artemia* could be attributed to high cost of imported *Artemia* (FAO 2011). No literature was found on the use of *Artemia* in the other East African countries. This could be attributed to the fact aquaculture is still mainly small scale as was reported in Tanzania (Chenyambuga, Mwandya et al. 2014). In Tanzania, Aquaculture was reported as subsistence activity for the poor households in some coastal and inland areas (Mallya 2007). At such small scale farmers common depend on the cheap green water cultures. Their fry production demands are not as high and therefore even with poor hatchery survival they can still have enough fingerlings for their subsistence production.

From the literature reviewed in this study, Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) were reported to be the leading aquaculture species in Africa with Egypt and Nigeria having the highest number of private commercial hatcheries, the majority of which were reported to be lacking an accreditation and certification systems and therefore unregulated (Brummett 2007). Uganda and other African countries like Cameroon, Ghana and Zimbabwe were reported to be mainly dependant on semi-commercial systems for seed production (Brummett 2007). This is in agreement with findings from Mwanja et al., (2015) where the majority of Ugandan hatcheries were reported to immediately wean fish larvae on natural feeds or a combination of natural feeds with dry feeds hence the low use of *Artemia* in Ugandan hatcheries. Many small hatcheries in Nigeria have been reported to wean and culture catfish larvae to fingerling in green water cultures (Adewumi and Olaleye 2011). Micro-algae and rotifers have been reported to be the main targeted feed from green water cultures. The choice of rotifers for weaning fish larvae was reported to have an advantage of low cost, with the difficulty to maintain pure cultures being the main disadvantage (Francis 2007). Commercial hatcheries being generally few, coupled with lack of regulation, accreditation, and certification systems in Africa; this makes information about hatchery practices to be very scarce hence information on use of *Artemia* in African hatcheries also being scarce.

Much as *Artemia* populations have been well studied in other continents like America, Europe and Australia, reports documenting local *Artemia* resources in Africa are scarce with extremely little work done on characterisation of the known local *Artemia* resources (Triantaphyllidis, Abatzopoulos et al. 1996; Triantaphyllidis, Abatzopoulos et al. 1998). Although *Artemia* population have been reported to be found in natural salt lakes and man-made salterns in the tropical, sub-tropical and temperate climatic zones (FAO 1996), no literature documenting local *Artemia* resources in Uganda was found in this present study. Previous unpublished findings from a short study funded by the Belgian Development Cooperation (BTC) in 2010 where lakes Katwe, Bunyampaka, Kikorongo, Murumuri and Bagusa were surveyed, indicated that these lakes had no local *Artemia* resources but with huge potential for *Artemia* production (un-published). Other than the speculations made about the existence of *Artemia* cysts on the shores of salt lakes in Western Uganda (Ogello, Kembanya et al. 2014), there is no literature confirming the existence of local *Artemia* resources in Uganda. This could be attributed to the fact that with the exception of a 2 day exploratory visits done in 2008 by Prof. Patrick Sorgeloos of *Artemia* Reference Center (ARC), Gent University in Belgium and the short feasibility study which was funded by Belgian Development Co-operation (BTC) in 2010 there have been no efforts directed towards identifying *Artemia* resources in Uganda.

Due to favorable environment like the hypersaline lakes and salt lagoons, most African countries have been reported to have potential habitats for *Artemia* (Ogello, Kembanya et al. 2014) and therefore potential for its production. The majority of *Artemia* populations in Africa have reportedly been collected in countries with a coastline. Among the Mediterranean countries to have *Artemia* resources include Algeria, Egypt, Libya, Morocco (Kara and Amarouyache 2012) and Tunisia (Triantaphyllidis, Abatzopoulos et al. 1998; Ben Naceur, Jenhani et al. 2008). Other African countries where *Artemia* resources have been identified include Kenya (MUÑOZ and PACIOS 2010), Madagascar, Mozambique, Namibia, Nigeria, Niger, Senegal, and South Africa (Triantaphyllidis, Abatzopoulos et al. 1998; Kaiser, Gordon et al. 2006). Most African *Artemia* habitats have been reported in countries bordering the Mediterranean region with Tunisia reported to have 23 sites (Ben Naceur, Jenhani et al. 2012), and this has been attributed to the high effort in the identification of *Artemia* resources in this region (Kaiser, Gordon et al. 2006). In 2010 Africa was reported to have a total of 92 *Artemia* localities, 57 of which are

undescribed with unknown reproductive mode, 8 and 5 of which were undescribed parthenogenetic and sexual *Artemia* populations respectively (MUÑOZ and PACIOS 2010). The 92 localities in Africa compared to the 172 in Europe is a small number bearing in mind that Africa is several times bigger than Europe and with a more favorable climate. This difference points to the gap that needs to be filled by increasing research efforts toward identifying more *Artemia* resources in Africa.

Although very few studies have been directed towards reproductive characterization of *Artemia* strains in Africa, both parthenogenetic and sexually reproducing populations have been reported (Triantaphyllidis, Abatzopoulos et al. 1998; Kaiser, Gordon et al. 2006; MUÑOZ and PACIOS 2010). It should be noted that a good number of *Artemia* resources so far identified in these African countries are not local but were rather intentionally introduced or accidentally introduced (MUÑOZ and PACIOS 2010), with some others being introduced by agents of *Artemia* dispersal like the migratory birds (Triantaphyllidis, Abatzopoulos et al. 1998; Munoz, Green et al. 2013). One of the well documented examples is the Kenyan *Artemia franciscana* which was introduced between 1984 and 1986 in a collaborative project between Kenya Marine & Fisheries Research Institute (KMFRI) and the Belgian Agency for Development Cooperation (BADC) with an aim of assessing the potential for *Artemia* production in the Kenyan coastal salt works (Radull, Rasowo et al. 1992; Mremi 2011; Ogello, Kembanya et al. 2014). *Artemia franciscana* is now reported to have spread along the Kenyan coast probably by agents of dispersals and has permanently established (Munguti, Kim et al. 2014; Ogello, Kembanya et al. 2014). Eight solar salt companies are reported to have *Artemia* inoculation policies with production in commercial and artisanal salt ponds already on-going (Ogello, Kembanya et al. 2014). More recently *Artemia* cysts genetically similar to Kenyan *Artemia franciscana* populations were reported at Tanga on the Tanzanian coast (Ogello, Kembanya et al. 2014). These might have been dispersed from the Kenyan coast but no literature pointing to *Artemia* production in Tanzania was found in this present study. Another example of intentional introductions are those of sexual *Artemia franciscana* used as live feed in aquaculture which was introduced in the Mediterranean basin and have been reported to be quickly replacing the native species (Amat, Hontoria et al. 2007; Kara and Amarouayache 2012). Since invasion success and impact depends on competitiveness and trophic interaction in the environment having the native and invasive strain and are sometimes irreversible and hard to predict (Amat, Hontoria et al. 2007), from biodiversity conservation perspective it is important local *Artemia* resources are developed other encouraging introductions of invasive species. It is worth noting that none of the reviewed literature pointed to commercial *Artemia* production in Uganda, with very little hint on commercial *Artemia* production in Africa.

Conclusions

Much as the distribution of *Artemia* is well studied in many countries in other continents like Europe, America and Australia, very little is documented about *Artemia*, its use, production and distribution in Africa. Even among the identified local African *Artemia* resources, a big majority is not yet developed to allow for commercial exploitation. Despite the urgent need for affordable *Artemia* resources for use in Ugandan and African aquaculture no literature confirms the existence of *Artemia* resources in Uganda with records of *Artemia* use in Africa still very scanty. This situation justifies the pressing need more than ever for documentation of *Artemia* use, exploitation and development of African *Artemia* resources.

Recommendations

For sustainable Aquaculture development in Uganda and Africa as a continent, more efforts in form of research and development need to be directed towards identifying, establishing and development of local *Artemia* resources. This will allow for improved survival in Ugandan and African hatcheries hence addressing the current shortages in quality seed supply from the hatcheries caused by lack of a suitable live starter feed.

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