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Hypochlorous Acid in Cattle Production: A Review of Applications, Efficacy, and Future Prospects in Sub-Saharan Africa

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Abstract: Hypochlorous acid (HOCl), a stabilized form of electrolyzed water, has gained attention as a potent, broad-spectrum antimicrobial agent across human and veterinary medicine. This review synthesizes current knowledge on the potential use of HOCl-based products in cattle production systems, with a particular focus on Sub-Saharan Africa. The antimicrobial, anti-inflammatory, and biofilm-disrupting properties of HOCl offer opportunities for improving cattle health, productivity, and biosecurity, while minimizing chemical residues and environmental impact. Documented benefits include reduced pathogen load on infrastructure, improved wound healing, enhanced water and feed hygiene, and possible improvements in animal growth and carcass quality. Despite these advantages, evidence on the efficacy and safety of HOCl in African cattle systems remains limited, particularly under smallholder conditions. Key knowledge gaps include its effects on indigenous breeds, role in maintaining dry-season body condition, and influence on blood and milk metabolites. Additionally, there is a lack of farmer-centred research exploring perceptions, adoption barriers, and practical implementation in resource-limited settings. The review highlights research priorities, including the need for locally relevant clinical trials, safety assessments, cost-benefit analyses, and studies incorporating farmer perspectives. A multidisciplinary approach integrating veterinary science, microbiology, environmental health, and socioeconomics is recommended. Overall, HOCl represents a promising, environmentally sustainable tool for advancing livestock health and productivity, evidence-based validation within Sub-Saharan African contexts is essential prior to widespread application.

Keywords: *Rural Livestock Systems, Sustainable Farming Innovations; Cattle Productivity.*

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I. INTRODUCTION

Livestock farmers need to have an inexpensive, available, nontoxic, and practical disinfectant that is effective in sanitizing their working environment for the welfare of animals and stockmen, improving quality of animal feed and water and treatment of livestock infections. An ideal product must be nontoxic to surface contact, non-corrosiveness, effective in various forms, and relatively inexpensive (Block and Rowan, 2020). In recent years, various forms of electrolyzed water have been promoted as a novel broad spectrum anti-microbial alternative to traditional solutions and medicine across various sectors which includes cosmetics, food industry, health, agriculture (figure 1) due to due to its non-toxicity to the environment (Rahman *et al.*, 2016). However there has been a number of issues related to utilisation of electrolyzed water which include limited knowledge on its decontamination mechanism, limited efficacy in food product, equipment surfaces, type of water used, presence of organic matter. Electrolyzed water with very low pH is corrosive due to high acidity and affect organoleptic properties of some feeds staffs which limits its use. Electrolyzed water with high pH is less effective. With the development of new technology to produce stabilized

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form of electrolyze water, some of the issues limiting efficacy of electrolyzed water are being solved. Such new products include Slightly Acidic Electrolyzed Water (SAEW); Slightly Alkaline Electrolyzed Water (SAIEW) and Hypochlorous Acid (HOCl). Products containing the stabilised form of HOCl (pH 6.5-7) as the active ingredient are currently being developed focusing on cattle production aspects. The current paper systemically review available literature on HOCl to help understand the role HOCl plays in various cattle production systems in Sub-Saharan Africa provides new insights into potential applications of HOCl for further research and development.

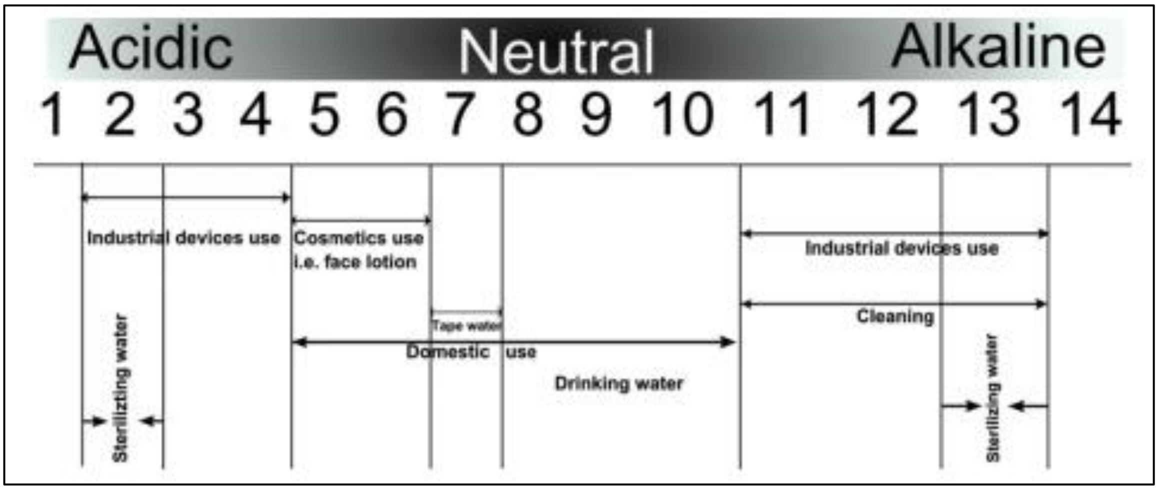

Fig 1: General Uses of Electrolyzed Water of Different pH
Adopted from Rahman *et al.*, 2016

II. HYPOCHLOROUS ACID

According to Block and Rowan (2020), hypochlorous acid (HOCl) is a mildly unstable compound generated when chlorine reacts with water. It is also endogenously produced in mammals as part of their innate immune defense mechanisms and naturally forms when chlorine dissolves in water as shown in figure 2. The body of mammals produce HOCl when nicotinamide and adenine dinucleotide phosphate oxidize in the mitochondria of phagocytic cells in the defence system and ensures that the phagocytized microorganisms are inactivated by breaking their DNA (Ateş, 2020). Synthetically, it is reported that HOCl is formed by acidification of hypochlorite, electrolysis of salt solution, reverse reaction of sodium hypochlorite and hydrogen peroxide, and hydrolysis of chlorine gas (Sakarya *et al.*, 2014; Gold *et al.*, 2020). HOCl was first exogenously produced in 1894, however there was no wide spread use due to its instability (Natarelli *et al.*, 2022). In recent years stabilized form of exogenously synthesized hypochlorous acid is a product of electrolysed (EO) water which is produced by passing a current of electricity through a dilute salt water solution (Bajgai *et al.*, 2020). Electrolyzed forms of HOCl have primarily been applied in high-demand settings that necessitate elevated concentrations of active chlorine, such as medical or industrial sanitation contexts (Bajgai *et al.*, 2020). Currently, in order to overcome the limitation of electrolytic HOCl, more advanced non- electrochemical HOCl product is under development and is applied in the fields of agriculture, livestock and food processing industry. Furthermore, some scholars are recommending the non-electrochemical HOCl for drinking water treatments because of possibility of harmful by-product generation such as metals and trihalomethane.

Literature on synthetically produced non - electrochemical HOCl is however still scarce therefore there is need to conduct studies to generate evidence on its efficacy and safety.

HOCl possesses a redox potential comparable to ozone, contributing to its broad-spectrum antimicrobial efficacy against bacteria, viruses, and fungi (Rahman *et al.*, 2016). Huang *et al.*, (2008) theorized that HOCL appears to kill microbial cells by inhibiting the oxidation of glucose by chlorine oxidising sulfhydryl groups of certain enzymes that are important in carbohydrate metabolism thereby causing damages to microbial cell membranes.

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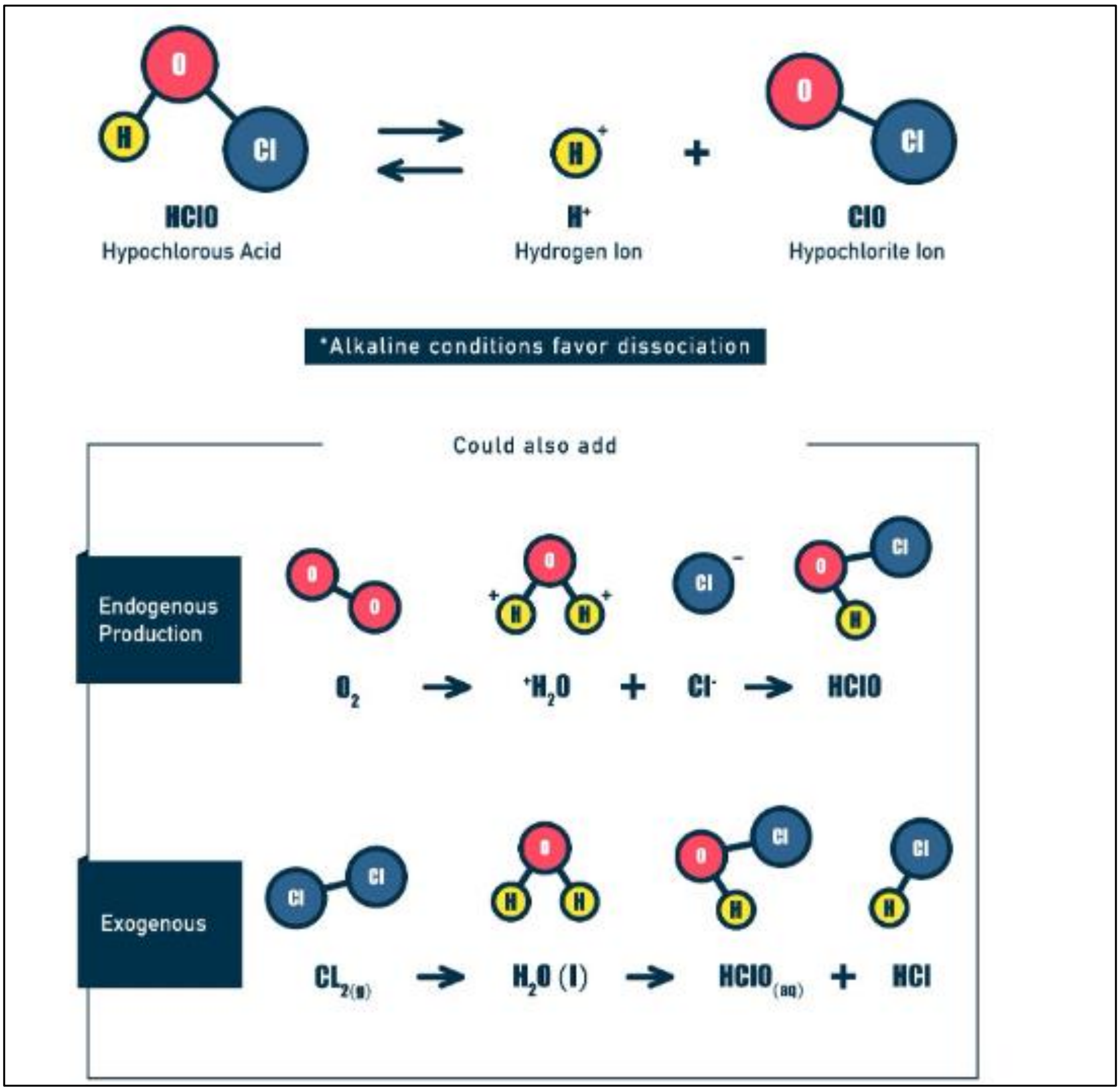

Fig 2: Hypochlorous Acid Structure and Formation
Adopted from Natarelli *et al.*, 2022

➢ *General Beneficial Effects of Hypochlorous Acid to Livestock Farming, Stockmen and the Environment*

HOCl is used in many industries such as farming, food industry, the health sector including chronic wound care and disinfection (Stroman, 2017). Table 1 summarizes some of the applications of HOCl across different fields. In the day to day life, HOCL is used for personal care, household surface cleaning, environmental cleaning as it is reported to be highly active against all bacterial, viral, and fungal human pathogens (Goto, 2015; Ateş, 2020). Reported benefits in the health services include as a remedy of superficial skin infections, acute and chronic wound, antisepsis of the operation site before and after the operation, mastitis, metritis, rhinitis, ocular and oral lesions, skin burns (Hakim *et al.*, 2015b; Gray *et al.*, 2016; Kim and Nam, 2018; Kanclerz *et al.*, 2019; Block and Rowan, 2020; Fam *et al.*, 2020; Gold *et al.*, 2020; Joachim, 2020). According to Sakarya *et al.*, (2014) small amount of HOCl can kill spore-forming and non-spore bacteria in a short time period therefor can be effectively used in cases where there are increases in fungal and bacterial activities in the environment. Furthermore, HOCl is active against biofilm and increases oxygenation of the wound site to improve healing (Gold *et al.*, 2020).

In livestock production HOCl has shown positive effects in infection prevention and improved animal health with reports improved broiler growth perfomances (Bajgai *et al.*, 2020). Additionally, lower cost, easy mass applicability, availability, and safety are some essential benefits that farmers can derive from the use of stabilized form of hypochlorous acid solutions as disinfectants on their animal farms (Hakim *et al.*, 2015b).

Table 1: Uses of HOCL

Field	Usage	Source
Medical	Dental device sterilisation; mouth wash, hand wash, endoscope sterilisation, wound and ulcer treatment, hospital floors sanitisation	Sakarya *et al.*, 2014; Block and Rowan 2020; Rahman et al. 2021; Gold *et al.*, 2020;

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Food Industry	Food washing, kitchen utensils sanitization	USDA, 2017;
Environment	Drinking water disinfection, air disinfection, waste water disposal, Swimming pool cleaning	Bajgai *et al.*, 2020; Llonchi *et al.*, 2023
Agriculture	Organic farming, fruit and vegetable washing Livestock Equipment and breeding houses sanitization, conjunctivitis treatment, skin treatment, removal of faecal odour, drinking water additive, diarrhoea prevention.	Bajgai *et al.*, 2020; Gard *et al.*, 2016; Goto 2015

➢ *Antimicrobial Properties*

Generally, hypochlorous acid has been shown to have anti-bacterial, anti-viral, anti-fungal and anti-algae effects including against enveloped viruses such as COVID-19 (Sakarya *et al.*, 2014; Hakim *et al.*, 2015a, Hakim *et al.*, 2015b; Bajgai 2020; Gold *et al.*, 2020). Species of microbes and diseases they cause are shown in Table 2.

Table 2: Microbe Species and Diseases they Cause

Type	**Pathogen**	**Infection type**	**Source**
Bacteria	*Moraxella bovis. Chlamydia spp., Neisseria catarrhalis, Mycoplasm spp*	Keratoconjunctivitis (Pink eye)	Gard *et al.*, 2016;
	Staphylococcus aureus; Pseudomonas aeruginosa; Candida albacan	Chronic Wounds	Sakarya *et al.*, 2014
	Escherichia coli	gastroenteritis, urinary tract infections, pneumonia, & bloodstream infections	
	Enterococcus faecalis	endocarditis, and bacteremia	Llonchi *et al.*, (2023)
	Basiluss	eye infections, meningitis, and sepsis	
	Shigella flexneri	bloody diarrhea, abdominal cramps, and fever.	
	Salmonella choleraesuis	Salmonella	Zastempowska *et al.*, 2017
	Staphylococcus epidermidis	Mastitis	Zastempowska *et al.*, 2017,
	Echinococcus granulosus	hydatid disease	Gökçe *et al.*, 2023
Virus	Ebola virus	Ebola	
	Corona virus	Covid 19	Block and Rowan 2020
	Alphainfluenzavirus influenzae	avian influenza	Hakim *et al.*, 2015a
Fungi	*Trichophyton verrucosum*	ringworm	Kolářová *et al.*, 2022
	aspergillosis,	respiratory system infections, mycotic mastitis	Kolářová *et al.*, 2022
	Mucorales	cause lymphadenitis and placentitis	
Protist	Theileria	East Coast fever	Kolářová *et al.*, 2022
	Anaplasma	anaplasmosis	Kolářová *et al.*, 2022
	Babesia	babesiosis	Kolářová *et al.*, 2022
	Trypanosoma brucei	trypanosomiasis	Kolářová *et al.*, 2022
	Eimeria and Cystoisospora species	coccidiosis	Kolářová *et al.*, 2022

➢ *Emerging Potential of Hypochlorous based Products in Cattle Production*

Hypochlorous acid (HOCl) based products hold significant emerging potential in cattle production due to their versatile applications and benefits for animal health, welfare, and farm management. Promising solutions in biosecurity, disease prevention, wound management, and eco-friendly to the environment in modern cattle production systems.

➢ *Cattle Infrastructure and Equipment Surfaces*

Use of HOCl based products as a preventative measure to disinfect cattle pens, milking parlours can increase productivity by ensuring animals are kept in healthy (Bajgai *et al.*, (2020). There have been studies that have looked at disinfecting cattle barns and milking parlours and equipment surfaces in general (Nickerson *et al.*, 2019; Hao *et al.*, 2014; USDA 2015). After cleaning of the chicken houses, rooms in which HOCl has been used for disinfection in the study had significantly lower bacterial counts than the rooms that underwent standard cleaning and disinfection (Hao *et al.,2014*). HOCl products can therefore be used to control mastitis and digital dermatitis, eradicate cryptosporidium by promoting good hygiene. However, all the clinical trials were done in the western world where production systems and climatic conditions are different to Sub-Saharan Africa.

There are no effective methods for reducing pathogens in smallholder dairy system milking parlour, cattle kraals and milking equipment as evidenced by the high levels of diseases such as clinical mastitis incidences, foot rot in summer. The incidences are caused by poor hygiene levels associated with smallholder dairy, however, there is limited information available on surface microorganism distribution across such systems. Hao *et al.*, (2014) highlighted that chemical

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disinfectants (benzalkonium chloride, formaldehyde, and glutaraldehyde) which widely used as a preventative measure against bacterial infections in livestock animals such as cattle, pig and poultry are potentially toxic, corrosive. Furthermore, there has been emergence of disinfection-resistant pathogens, such as Listeria monocytogenes, which displays cross-resistance to chemical disinfectants. There is therefore need to improve current measures to control pathogens populations in in smallholder dairy system milking parlour environments and milking equipment, through development of effective alternative disinfectants with less residues. It can be theorized that HOCl based organic remedies are is an effective bio-decontaminant of pens, parlour, milking equipment, and teats however there is to check its efficacy under a smallholder dairy cattle production system which is characterise the majority of small holder milk farms in Sub-Saharan Africa.

➢ *Wound Healing and Antibiofilm*

Currently there are no studies which have been reported on HOCl based product as a castration and dehorning wound care in cattle. It can however, be hypothesized that products with HOCl as an active ingredient will be effective as post dehorning and post castration wound remedies as it has been shown to be highly effective agent in reducing wound bacterial, viral and fungal counts in open wounds for humans (Hiebert and Robson 2016). Further empirical studies are essential to validate the proposed effectiveness of HOCl in managing post-castration and dehorning wounds in cattle, given the limited available data in veterinary contexts. There have been extensive studies in the human medical field on use of HOCL for intraperitoneal wound care where HOCl has been shown to be an effective agent in reducing wound bacterial counts in open wounds with no adverse effects were observed (Kubota *et al.,* 2015; Joachim 2020). A review by Gold *et al.,* (2020) concluded that for wound care and scar management, topical stabilized HOCl conveys powerful microbicidal and antibiofilm properties, in addition to potency as a topical wound healing agent. In vitro studies by Sakarya *et al.,* 2014 observed that the stabilized HOCl solution had dose-dependent favourable effects on fibroblast and keratinocyte migration compared to povidone iodine which led to conclusions that a stabilized HOCl solution is an ideal wound care agent. Further large-scale clinical studies in-vivo are however necessary to confirm the observe phenomenon on farm animals. Both iodine and chlorhexidine which are effective antimicrobial have been shown to have deleterious effects at high concentration and may potentiate wound infection and inflammation (USDA, 2017). There is therefore a need to search for alternative solutions to use in cattle wound care. Even though hypochlorous acid has mostly been tested in treatment of human wounds, reported success makes conceivable that its efficacy will be the same in cattle wounds. Studies are therefore required to better understand the effect topical hypochlorous acid has on re-epithelization in comparison to other wound remedies used in cattle treatment.

➢ *Skins Infections*

No studies have been reported on therapeutic effect of HOCl in bovine skin such as fungal dermatophytosis. Babur and Karademir (2023) concluded that HOCl has an effect on dermatophytosis of cat and dogs, although not as much as antifungal remedies currently on the market and recommended for further studies to evaluate their finding. HOCl is also effective at degrading biofilm to reduce bacterial growth on the skin (Hao *et al.,* 2014). Odorcic *et al.,* (2015) and Romanowski *et al.,* (2020) however noted that HOCl cause deformation on fungal agent through destroying cellular electron transport chains and the adenine nucleotide pool in clinical human trials.

➢ *Pink Eye Treatment*

Infectious bovine keratoconjunctivitis (pinkeye) is problematic in Sub-Saharan Africa due to house flies, high sunlight radiation levels and rangeland dust in dry season. Results from the study by Gard *et al.,* (2016) suggest that hypochlorous acid spray can be effectively utilized as alternative therapy to reduce pain, infection, and healing time of corneal lesions in calves infected with *Moraxella bovis.* Many other antimicrobials which can effectively treat pink eye such as penicillin, sulfadiamethoxine, cephalosporins, florfenicol, enrofloxacin, as well as myriad of topical preparations such as triple antibiotic, gentamicin, and oxytetracycline ointments are discouraged for pink eye treatment due to the potential for prolonged tissue residues and longer withdrawal period in which affect farm productivity in milk and meat production systems as the produce will have to be discarded (Angelos 2015; Gard *et al.,* 2016). This make HOCl ideal for treatment of pink eye which regularly affect animals in feedlots and dairy cows in on zero grazing, however there is need for further economic evaluation of such HOCl to determine the full economic advantages that farmers might receive with its use when compared to currently approved antibiotics, such as oxytetracycline.

➢ *Water Quality and Consumption Rate*

Water is a vital yet often underemphasized nutrient in livestock nutrition, despite its critical role in feed intake and productivity (Devant *et al.,* 2019; Hansen, 2019). Limiting access to drinking water impairs animal welfare and may result in less feed consumption and consequently less animal productivity. Livestock technical advisory officials and farmers tend to focus more on other aspects of cattle production and nutrition and fail to consider impact of water as a possible source of disease and low herd performance (Vargas-Bello-Pérez 2021). Cattle in most Sub-Saharan African countries which includes Zimbabwe smallholder farming community drink water from open sources which are often contaminated by faeces and various debris. Fighting the bacteria in poor water means they are putting more energy into their immune systems, and less into growth and performance. Studies have shown that contaminated water can be a source of pathogenic bacteria, viruses, protozoa, and helminths (WHO, 2022). Chlorination is the most common water disinfection treatment; however, its effectiveness is limited by water pH and, therefore, water acidification may be necessary (Llonchi *et al.,* 2023). One farm in Wales has used HOCl to solve a serious problem with Cryptosporidium contamination. Solosan^{tm} with HOCl as an active ingredient was used to clean the calf stalls and calf buckets, as well as treat their drinking water. However, the study methodology is

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unclear it does not give adequate information on the method of randomisation and process of treatment allocation. Larger randomized controlled trials are required to further assess the efficacy, although this appears a promising field of novel research. Bajgai *et al.,* (2020) indicated that even though electrolysed HOCl has shown positive effect such as infection prevention and improved health in livestock but the evidences of drinking effects of HOCl are still insufficient. There is therefore a need for further studies in this regard.

A study by Llonchi *et al.,* (2023) evaluating effect chlorination and acidification of drinking water on Holstein steers feedlot performance reported that drinking water chlorination and acidification in fattening dairy beef bulls is recommended as it improves growth performance without any detrimental side effects on health or nutrient digestibility. The authors hypothesized that drinking water treated with H3PO4 and NaClO 15% m would increase animal productivity by increasing water quality and consumption without any negative effects on the animal's health. While hypochlorous acid was not part of the treatments in the reported study, it is possible that its effect mirrors that of hypochlorite. Future work is required to assess the effect of HOCl in feed on cattle growth rates and carcass quality. Additional studies are required to better understand the effect hypochlorous acid as a feed additive and to ascertain if it can be effectively used to improve poor quality feeds such as cereal stover and veld harvested hay which is used for supplementation by the majority of smallholder farmers in Sub-Saharan Africa.

➢ *Apparent Total Tract Digestibility, Animal Performance and Carcass Quality*

In their study, assessing efficacy of H3PO4 which is closely related to HOCl, Llonchi *et al.,* (2023) observed that while water consumption was similar across treatments (untreated water; H3PO4 water; NaClO water; H3PO4 & NaClO water), there were significand improvements in feedlot performance of Holstein steers drinking acidified and chlorinated water compared to those drinking untreated water in term of daily weight gain, daily feed intake. The authors could not attribute the observed phenomena to increase in concentrate alone as the alluded that the mechanisms by which water chlorination and acidification improved performance parameters are not truly understood yet. In the same study, animals drinking H3PO4 conditioned water had similar nutrient digestibility, such as CP and EE, suggesting that long-term consumption of water disinfection does not significantly affect digestibility after initial adaptation period. From these observations, it can therefore be hypothesized that HOCl will have similar effect on feedlot performance of animals. Future work should be conducted to assess effects of HOCl on apparent total tract digestibility, daily feed intake and weight gain.

➢ *Maintenance of Cattle Body Condition Score*

Sub-Saharan Africa cattle farmers have been enduring problems associated with dry season low plane of nutrition and droughts which are becoming more frequent due to effects of climate change. Throughout such periods, animals mainly survive on poor quality grasses and crop by-products which can have as little as 3% crude protein content with minimum supplementation, leading to low animal performance (Mapiye *et al.,* 2010). Low plane of nutrition results in poor body condition in cattle which has a negative effect on overall farm productivity through reduced reproductive performance of cows due to various inherent problems like delayed puberty, a smaller number of primary follicles, silent estrus, irregular time of ovulation, foetal embryonic deaths, nutritional stress induced abortions and long postpartum anoestrous (Centurion-Castro *et al.,* 2013). All these factors point to the effect of body condition score in various performance traits of economic importance. Hence, regular evaluation of novel user-friendly non-toxic feed and water additives with potential to aid in dry season body condition score maintenance and growth rates by improving water and feed quality, is of paramount importance. Remedies with hypochlorous acid, as the active ingredient of the product, can improve water and feed (hay, bush-meal and foggage) quality which will result in enhanced dry season cattle performance. Therefore, there is therefore need to conduct clinical trial to generate data on the effectiveness of such novel treatments in maintaining the dry season body condition score and growth rate of cattle in communal areas where 90% of animals are found.

➢ *Beef Carcass Presevations and Meat Quality Parameters*

Research has explored different application methods for HOCl treatments, including spraying, dipping, and injection. While there isn't extensive research specifically focused on beef meat quality preservation using hypochlorous acid (HOCl), there are studies that explore the antimicrobial effects of electrolyzed water on meat quality preservation (Yan *et al.,* 2021). Evidence from the few studies conducted have demonstrated the efficacy of HOCl in reducing microbial contamination on meat surfaces (Veesey and Muriana 2016). For example, research has shown that HOCl treatments can effectively reduce the levels of pathogens such as *E. coli, Salmonella,* and *Listeria monocytogenes* on meat carcasses and cuts. By reducing microbial load and inhibiting spoilage organisms, HOCl can increase shelve life of beef. While fewer studies have directly examined the impact of HOCl on meat quality parameters such as colour, texture, and flavour, some research suggests that HOCl treatments may have minimal adverse effects on these attributes. However, further research is needed to fully understand the impact of HOCl on beef sensory characteristics.

➢ *Cattle Slaughterhouses Bio-Decontamination*

Several authors have compared effectiveness of electrolyzed water with other chemicals as an abattoir bio-decontaminant and reported that electrolyzed water was more effective for inactivating bacteria in various units at slaughterhouses (Young *et al.,* 2016; Cavalheiro *et al.,* 2022). Its use in Sub-Saharan Africa, Zimbabwe abattoirs in particular, could significantly reduce contamination risks of saprophytes and pathogens such as *E. coli* which have been noted to easily transfer from hides to carcasses during skinning (Arthur *et al.,* 2004). Viltrop *et al.,* (2023) has established that adding disinfectants to spraying or misting water is effective in reducing microbial and *Salmonella*

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bacterial counts from hides in addition to the maintenance and optimization of slaughter hygiene practices.

- *Somatic Cell Count*

Somatic cells count (SCC) are an indicator of mastitis and subclinical mastitis in dairy herds (McParland *et al.*, 2019). Investigating the effect of HOCl on milk metabolites related to mastitis prevention, such as somatic cell counts and milk protein profiles, is critical for evaluating its efficacy in dairy production. Vargas-Bello-Perez *et al.*, (2020) observed a decreased somatic cell counts (SCC) when dairy cows consume electrolyzed chemical water. This may suggest that electrolyzed chemical water of which hypochlorous acid is the active ingredient can be an alternative to control mastitis incidences, however their study was short term and only based on 5 cows so the result is debatable. A more comprehensive study is required to generated empirical evidence for conclusive data on the efficacy of HOCl based water in control of mastitis as well as the specific mechanism by which HOCl decreases milk SCC. Future studies should not only be limited on performance of dairy animals consuming HOCl water but should also include efficacy of HOCl based products as a bio-decontaminant of pens, parlour, milking equipment, and teats in control of mastitis.

- *Blood and Milk Metabolites*

Monitoring blood metabolites associated with growth, metabolism, and stress can provide insights into the overall health and productivity of cattle receiving HOCl based products. Vargas-Bello-Perez *et al.*, (2021) noted that there is a paucity of information on the effects of electrolyzed chemical water on different metabolites in blood, milk, urine and faeces. These analyses are critical to understand the long-term impacts of HOCl on general body metabolism of cattle and mammary gland health of dairy cows. There is therefore need to conduct studies to generate knowledge on effects of HOCl metabolites in blood, milk, urine and faeces. HOCl may affect the immune response in cattle, which could lead to changes in blood metabolites such as cytokines, acute-phase proteins, and immunoglobulins. HOCl's antimicrobial properties may influence inflammation levels, potentially affecting markers such as C-reactive protein (CRP) or pro-inflammatory cytokines in the bloodstream. HOCl is one of reactive oxygen species naturally found in dairy cows suffering from oxidative stress in during transition period (±3 weeks pre and post calving) due to increased levels of Non-Esterified Fatty Acids (NEFA). Reactive oxygen species are known risk factors for mastitis, retained foetal membranes, ketosis and fatty liver disease in transition cows (Abuelo *et al.,* 2015). There is therefore a need to study transition cows drinking HOCl water to check if it has no negative effects on the animals. The research could investigate its impact on blood antioxidants (e.g., glutathione) and oxidative stress markers (e.g., malondialdehyde) in cattle.

HOCl treatments in lactating dairy cows could also potentially affect milk composition, including fat, protein, lactose, and somatic cell counts. Assessing the impact of HOCl on milk quality parameters such as acidity, pH, and microbial contamination is crucial for ensuring food safety and product quality. Studies should be conducted to evaluate the presence of HOCl residues or metabolites in milk and their potential impact on human health.

III. POTENTIAL HAZARDOUS EFFECTS

- *Cattle*

In general, literature suggests that hypochlorous acid is well-tolerated by livestock (Gard *et al.*, 2016; Block and Rowan 2020; Gold *et al.,* 2020), however there is need to ascertain concentrations which are safe to cattle for the various applications. Pelgrift and Friedman (2013) caution that high-dose or lengthy cutaneous exposure may actually increase pruritus by causing conditions in which itching is a primary symptom, such as irritant contact dermatitis and allergic contact dermatitis (Natarelli *et al.,* 2022). Studies are required to determine the concentration of hypochlorous acid that maximizes efficacy yet minimizes irritation for specific indications in cattle, such as dehorning burn wound and post-surgical castration healing and atopic dermatitis.

- *Farmers*

Several studies have shown that HOCL based solutions are less toxic to humans compared to other chlorine-based disinfectants (bleach variants) have been shown to cause occupational dermatitis or skin irritation (Block and Rowan 2020; Natarelli *et al.,* 2022). Furthermore, in contrast to chlorhexidine, HOCl, used as an antiseptic skin preparation, raises no concerns of ocular- or ototoxicity (Gold *et al.*, 2020). However, it should be noted that there is no chemical which is 100% non-toxic, the most common adverse effect of HOCl is host protein denaturation when ingested. This was been the main reason for non-use of such HOCl based solutions in some countries like USA prior to 2018 when it was approved (USAD 2018). Winterbourn and Kettle, 2000 observed the toxicity of HOCl, which so effectively eliminates invading pathogens, can also cause damage to the human tissue.

Research by Pullar *et al.*, 1999 showed that HOCl treatment in endothelial cells also lead to ATP depletion and irreversible loss of glutathione. At chronic inflammation sites, myeloperoxidase activity and the HOCl specific biomarker, 3-chlorotyrosine, are commonly detected. Further analysis showed that the apoptosis-like cell death is induced by HOCl in human mesenchymal progenitor cells (Whiteman *et al.*, 2007). To elucidate the mechanism by which HOCl kills bacteria and destroys human tissue a detailed understanding of the phagocyte-derived HOCl formation during pathogenic events and the biochemistry of HOCl reactivity is therefore needed. There is therefore a need for need for regular research to asses potential adverse effect of any new HOCl based cattle disinfectants and products as some research have clearly shown that they HOCl is not 100% safe depending on use and to gain farmer perspectives on these products.

- *Environment*

Several authors have highlighted that commercially produced hypochlorous acid at pH 6.5-7.5 is safer to use compared to other disinfectants containing chlorine as it is made from water and salt, there are no by-products disposed to the environment (Gold *et al.*, 2020). HOCL is not harmful to cattle and humans as all mammal bodies produces it as an endogenous substance in low concentration and contain 10 000 times less chlorine than other common disinfectants with bleach yet is as effective as any chlorine treatment. Moreover, it has effective anti-microbial action effective against a broad range of microorganisms in comparison to many synthetics antibiotics currently utilised and are known to have various adverse side effects which include diarrhoea, loss of appetite and may destroy good microbes found in the animal's digestive system. Bajgai *et al.,* (2020) indicated that HOCl has no such adverse effects following usage as an antimicrobial agent. It has however been noted that hypochlorous acid in aqueous solutions at pH< 7 could be very toxic to fish and freshwater invertebrates with minimal toxicity to birds. There is potential for detrimental chemical interaction with organic material (humic acid) however carcinogenic and teratogenic trihalomethanes and halo-acetic acids are not formed by the action of hypochlorous acid in neutral or near-neutral solutions.

- *Cost of HOCL based Products*

Several authors have alluded that compared with alcohol-based disinfectants, the cost HOCl is much lower (Naka *et al.,* 2020). Furthermore, sterilization time is much faster as well as versatility since it is effective against a broad range of organisms. From an economic perspective, if claims of remedies with HOCL are proven to be true, cattle farmers will therefore have a cheaper and more effective low risk alternative solution at their disposal. Gellynck *et al.*, 2008 analysed the economics of reducing *Campylobacter* to different levels within the poultry meat chain (farm, processing plant, and consumer) and found that the decontamination of carcasses with AEW in the processing plant was the most efficient (cost-benefit ratio) of the evaluated measures. Similar studies can be conducted for the cattle value chain in Sub Saharan Africa for HOCl based products. The studies should include comparing cost of HOCL based products treatments with the potential benefits such as improved health, reduced disease transmission and increased productivity.

- *Geographical Limitation of Application of Hypochlorous based Solutions in Cattle Production in Sub-Saharan Africa*

Currently a meta-analysis which can be conducted over a scan through the web produce no scholarly articles on clinical trials on HOCL done in Sub-Saharan Africa cattle sector besides ceremonials used by companies marketing their products. Ceremonials do not provide conclusive data on effectiveness of a product to form the basis for introducing novel solutions without empirical evidence as they tend to be biased towards promoting product manufacturers. There is therefore a need for proper, non-biased, randomised research trials, with methodologies which are repeatable to generate empirical evidence of the efficacy of the HOCl under local cattle production systems and climatic conditions.

- *Study Design Frameworks for HOCl Concepts in Sub-Saharan Africa Cattle Production Systems.*

Several trials done on potency of HOCl have been limited to the clinical aspects. Such studies have created knowledge gaps on farmer perspectives which is critical since the farmer is the targeted end user of the new technology. Insights on how cattle stockman and farmers in general views a new technology or product is critical in creating and further refining the product to suit needs of the particular farmer groups as their perceptions significantly impact on whether the product will be adopted or not. Researches done on HOCl seek to develop a product with less toxicity to the environment yet they are not taking views of the stockmen to gauge if HOCl based product have no adverse effect to the farmer and animal well according to the farmer's view. Conceptually, the decision to adopt or not adopt a product is a function of farmers' perceptions of that product compared to other innovations or technologies available to them. There are several reasons why farmers may adopt a new product. Some farmers perceptions may be influenced by the information available to them, their socioeconomic situation and their production system. Adoption is the extent to which farmers put into practice a new innovation in the future, given adequate information about the technology and the potential benefits (Mwangi and Kiureke 2015). Future trials that seek to validate concepts or test products developed elsewhere for efficacy in local communal farming systems should therefore merge clinical trial with adopter-perceptions theoretical frameworks which identifies farmers' perceptions as being key to the adoption of farming technology or product and use the theory to develop a conceptual understanding of the research problem. This is of significance as it will generate new knowledge and insights on how farm stockmen perceive potential challenges and benefits that could be derived from adopting the use of hypochlorous acid-based solutions in cattle production systems as an alternative method of improving productivity. The information is critical in designing models and roll out methods of such products for better acceptance and optimum utilisation by farmers.

IV. CONCLUSIONS

Though promising, claims of efficacy of HOCl based products in cattle need to be studied further for the various effects it's been claimed to have as there is currently no comprehensive literature on the various efficacy claims which include cattle body condition score maintenance, growth performance, udder health (somatic cell count) and carcass quality improvement under Sub-Saharan Africa cattle production systems. Furthermore, there have been no studies on effect of HOCL that have been reported in indigenous cattle across Africa. Globally there is still knowledge gaps in specific efficacy of HOCL as a castration and dehorning wounds bio-contaminate, in dry season body condition score maintenance as there are no reported findings to confirm this in cattle. The broad claims surrounding HOCl's efficacy necessitate rigorous scientific validation through clinical trials, particularly within the context of indigenous cattle systems in Sub-Saharan Africa. Future studies design frameworks should therefore also include farmer and stock

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people perceptions as well as animal welfare instead of just concentrating on clinical trial aspects.

Overall, evaluating the efficacy of HOCl based products on cattle productivity requires a multidisciplinary approach that considers that considers microbiological, veterinary, economic and environmental factors to determine its potential for farmers and cattle. The evaluations should also include assessing potential side effects, residue levels in in milk or meat and environmental impact associated with use of HOCl. Continued research on HOCl-based products can generate new knowledge which will contribute to improved animal health, welfare, and productivity while ensuring the long-term sustainability of cattle production systems. The studies should include factors such as dose, duration of treatment, animal and production system to provide meaningful insights into the potential benefits and risks associated with HOCl based products.

- *Author Contributions*

Conceptualization, writing of original draft - Bruce Tavirimirwa: review and further review and writing and editing of manuscript – Bruce Tavirimirwa, Sikhulile Siziba, Patience Dera, Tendai Dominic Matekenya, Gevious Sisito, Xavier Zhakata, Butholezwi Ngulube.

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