Water: the critical nutrient for ABF production

Water quality becomes increasingly important in antibiotic-free production systems. Dr DEXTER ABRIGO* discusses how acidifiers can be used to reduce bacterial growth in drinking water.

Water is involved in many aspects of a bird's metabolism. It helps in regulating body temperature, aids in digestion, and helps in removing wastes from the body. At thermo-neutral temperatures, chickens consume two times more water than feed, and in periods of high temperature, the consumption rate can double or even increase four-fold. Therefore, it is safe to assume that when birds' water consumption is down, feed consumption will also be down.

There are several factors that can indicate water quality such as taste, odor, and color, as well as the presence of bacteria or other microbes, mineral levels, and other chemical and physical factors. When we talk about chemical and physical factors, pH is probably the quality that can be most effectively influenced.

pH is a measure of the alkalinity or acidity of the water and though the ideal water pH for broilers is between 6-8, birds can tolerate a low pH of 3.5. Water with a very alkaline pH, or a pH higher than 8, may cause birds to refuse drinking, likely due to decreased palatability. Another quality of water is hardness. Hard water has more magnesium and calcium ions while soft water has more sodium ions. Hard water causes scale build up in water pipes resulting in slower water flow, decreased water consumption then decreased feed intake. Although not always directly correlated to pH, hard water generally has a high pH.

Water includes dissolved nutrients. Phosphorous and nitrogen have been found to aid in the growth of bacteria and algae in water through a process called eutrophication.

Over time, bacteria or algae tend to form a visible slime layer, or what is commonly referred to as biofilm inside the water pipes. Biofilm is a community of different bacteria that have enclosed themselves within a "wall" for survival and are attached to a hydrated surface. Aside from biofilm, mineral build up, such as magnesium, iron, sulfur, sodium and copper in water pipes may cause water rejection due to decreased palatability or can cause diarrhea. Reducing water pH has been observed to reduce or even remove both biofilm and mineral build up in water pipes.

Chlorination has been one of the most accepted and practiced method of water sanitation not only for poultry consumption but for humans as well. Commonly used chlorine sources such as sodium or calcium hypochlorite, will create, under optimal pH (pH<6.5) and upon hydrolysis, hypochlorous acid, which has a strong germicidal action. Under high pH conditions (pH> 8.5) instead of producing hypochlorous acid, hypochlorite ions are produced, which has less germicidal action. Chlorination on the farm is much more effective under low pH conditions, which may require acidifying the water to achieve an optimal pH level. It should be noted that certain acidifiers, when used with chlorine, may produce certain noxious gases like chlorine gas, and consequently should be mixed and injected separately.

Reducing the pH of water can result in several benefits, such as improved palatability, reduced amount or removal of biofilm, improved effect of chlorination, and antibacterial effect (Table 1) not only in the water but also in the gut of birds.

Perhaps the most important benefit of lowering pH, especially in the advent of antibiotic growth promoter-free (AGP) or antibiotic-free (ABF) production, is the antibacterial effect on water quality and also in the gut of the bird. According to several studies, coliform bacteria contaminates around 40% of water used on poultry farms in the U.S. and in some regions of the world 70% of water supplies are contaminated with coliform bacteria. Albeit necessary, water is a risk factor to poultry health as it is one of the routes for disease infection

Table 1. The effect of pH against *E. coli*, *Salmonella* and *Clostridium*.

pH	*E. coli*	*Salmonella*	*Clostridium*
6.4	++++	++++	++++
6.0	+++	+++	++++
5.8	++	++	++++
5.4	+	+	+++
5.0	-	+	++
4.5	-	-	+
4.0	-	-	-

Susan Watkins et al., 2005. The more "+" the better the bacteria grows

Table 2. Different pKas of common organic acids.

Acid	Formula	pKa
Formic	H COOH	3.75
Acetic	CH_3COOH	4.76
Propionic	CH_3CH_2COOH	4.88
Butyric	$CH_3CH_2CH_2COOH$	4.82
Lactic	$CH_3CH(OH)COOH$	3.83
Fumaric	COOHCH:CHCOOH	3.02
Citric	$COOHCH_2C(OH)(COOH)CH_2COOH$	3.13
HMTBa	$CH_3SCH_3CH_2CH(OH)COOH$	3.53
Benzoic Acid	C_6H_6COOH	4.20
Sorbic	$CH_3CH:CHCH:CHCOOH$	4.76

Figure 1: Percent inhibition of *E. coli* with different organic acids [055:K59 (B5):H, %].

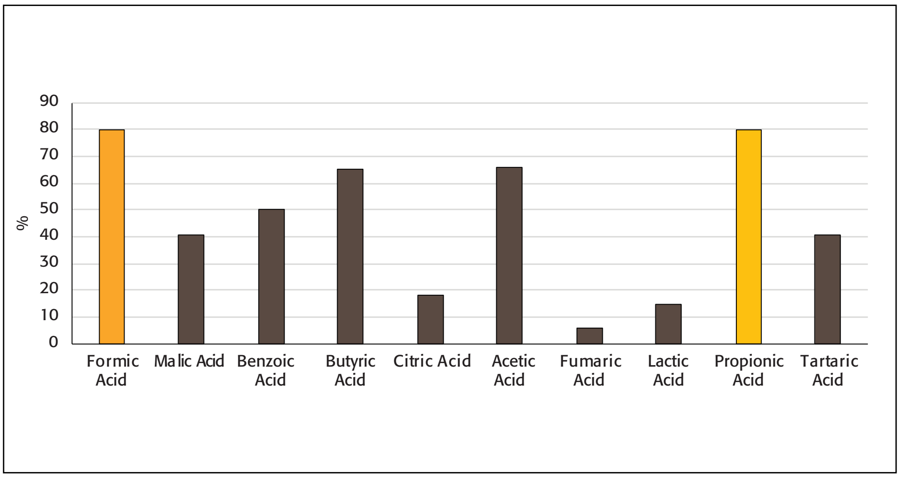


Figure 2: The efficacy of formic, propionic and lactic acid against several important disease-causing bacteria.

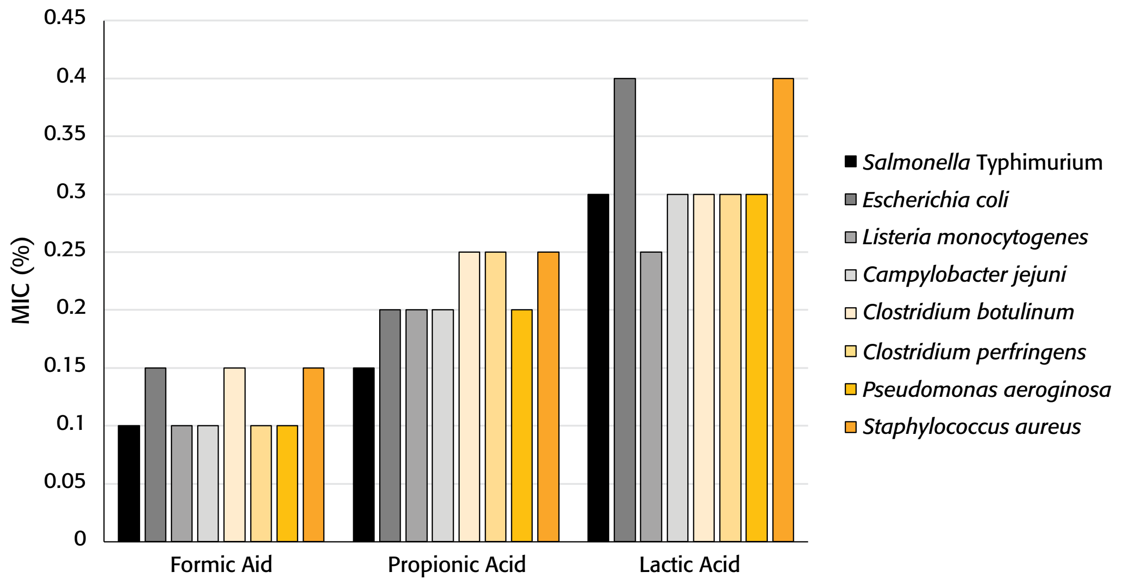


Figure 3: HMTBa and formic acid activity (free and salt form) against *Salmonella* Enteritidis.

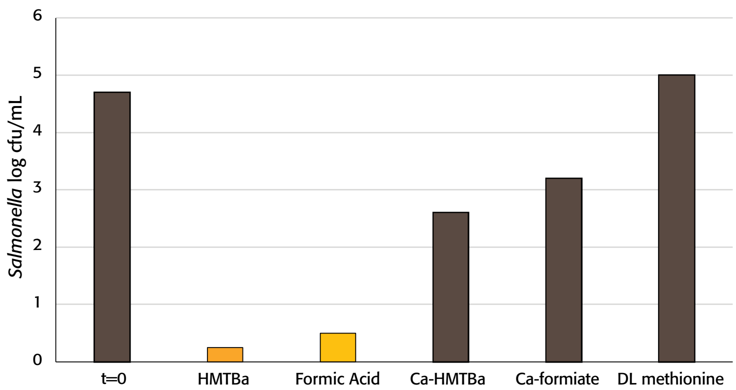
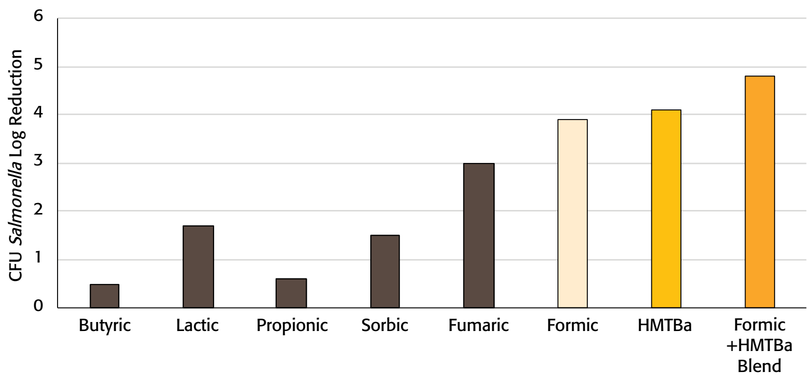


Figure 4: Comparison of HMTBa versus other organic acid and a commercial product containing HMTBa.



and transmission. Some bacteria and virus-causing diseases that can be potentially transmitted by water are *Mycoplasma, E. coli, Pasteurella,* Newcastle disease virus, Infectious bronchitis virus and Marek's disease caused by a herpesvirus. Zoonotic diseases caused by *Salmonella* and *Campylobacter* can also be transmitted or transferred through water and found in biofilm samples. Acidification of water is one of the best ways to control and prevent these types of diseases in poultry.

The role of organic acids

As the practice of lowering the pH through water acidification increases, more and more products have become available in the market. Most acidifiers are a blend of different organic acids, with claims of acidification alone resulting in bacterial reduction, and improved gut health, performance and food safety. Organic acids are either simple monocarboxylic acids (formic, acetic, propionic and butyric), carboxylic acids with hydroxyl groups (lactic, malic, tartaric and citric acids), or short chain carboxylic acids containing double bonds (fumaric and sorbic acids). However, not all of these acids have microbial activity and can affect the gut microflora. Organic acids with specific microbial activity are short chain acids (C1-C7), sometimes bound to sodium, calcium or potassium as salts, with a pKa of between 3-5. pKa, or acid dissociation constant, is the pH value wherein 50% of the organic acid is dissociated and 50% is undissociated. Strong acids, having greater ionization, will have a lower pKa, while weak acids, having less ionization, will have higher pKa. Table 2 shows the different pKas of some common organic acids.

Each acid has its own spectrum of antimicrobial activity. Propionic acid is commonly used as a mold inhibitor in raw materials and feed, while formic acid is well documented as an effective organic acid against *Salmonella, E coli* and *Clostridia.* Another organic is citric acid, widely used as a water acidifier as it is inexpensive, but has low antibacterial properties compared to formic acid. Figures 1 and 2 highlight the efficacy of formic acid and other acids versus disease-causing bacteria.

Blends of organic acids were introduced to the industry following several studies that showed some acids have synergistic antimicrobial activity. It is well known that the efficacy of organic acids varies widely with the type of acid or blend of acids used, the physical nature of the acid, the inclusion rate, and whether the products are present as free acids or salts.

HMTBa

HMTBa, or 2-hydroxy-4-methylthio-butanoic acid is an organic acid that when absorbed in the animal's gut serves as a source of methionine, a limiting amino acid. Having a pKa of 3.53, HMTBa has an antibacterial action the same or equal to that of formic acid (Figure 3).

All acids (blend) added a constant level of 1% per ton of complete feed

As mentioned earlier, organic acids have been known to have synergistic effects once combined. The same is true for formic acid and HMTBa. Being both strong acids and effective against *Salmonella,* the resulting blend has been shown to be more effective compared to individual acids (Figure 5).

It is clear that the antimicrobial activity of organic acids will depend on their ability to influence pH. It has also been shown that different organic acids will have different effects on different bacterial organisms. Studies have determined that formic acid seems to be the best candidate as an antibacterial especially against *Salmonella* while a combination of formic acid and propionic acid has shown to improve weight gain and has influenced bacterial populations in the gut.

Water pH trials in Southeast Asia and Pacific

As pH of water is an important quality, not only to reduce bacterial contamination in the water itself but also in the bird's gut, a series of field trials were done to test how different organic acid combinations perform in reducing the water pH. A trial was

Figure 5: Study combining formic and HMTBa organic acids tested against *Salmonella* enteritidis reduction.

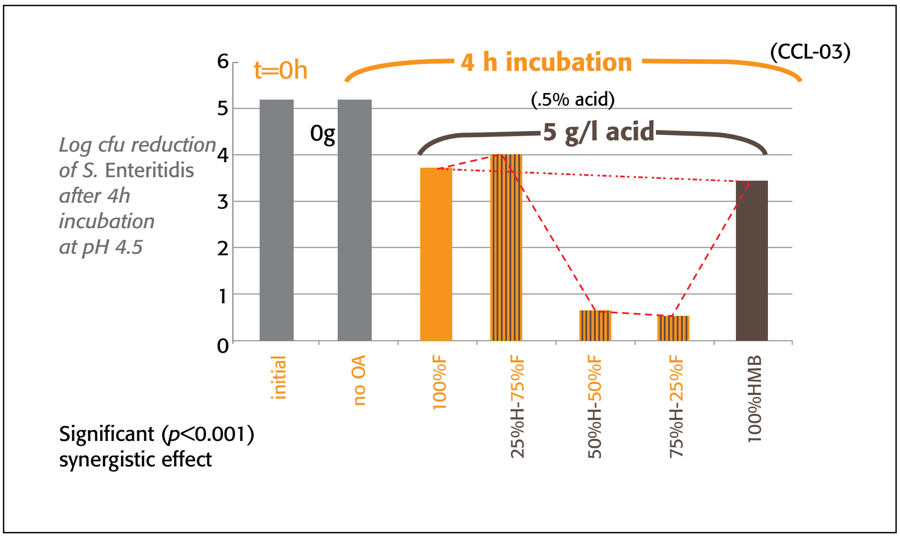
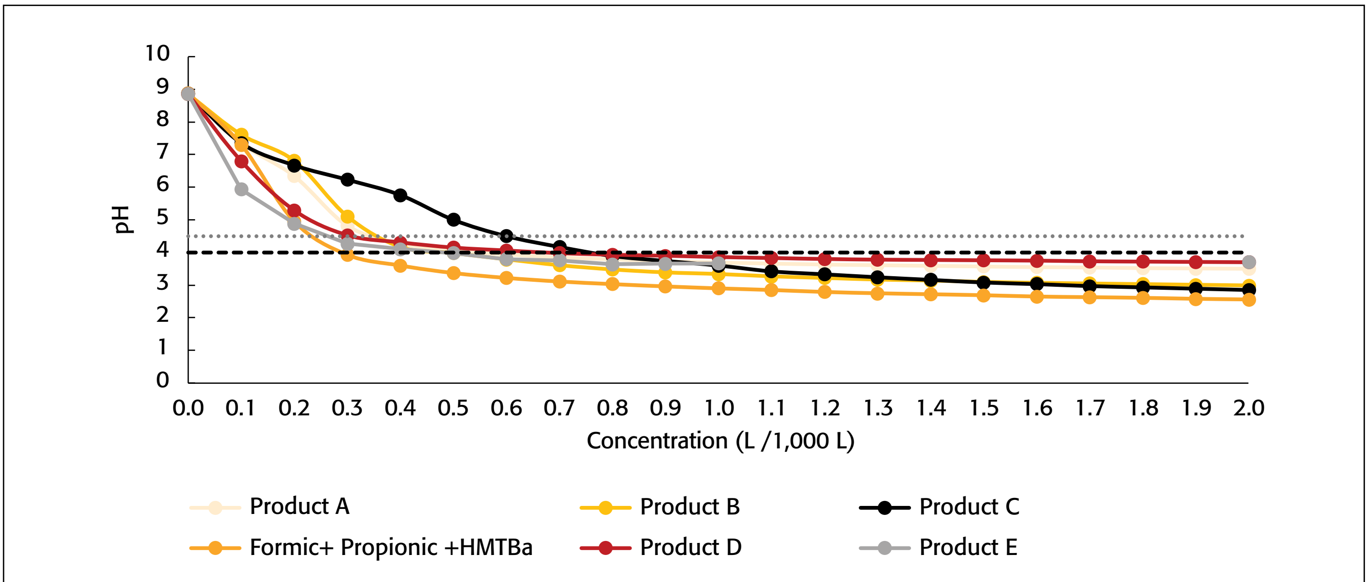


Figure 6: pH titration study done with formic+propionic+ HMTBa compared to different organic acid combinations.

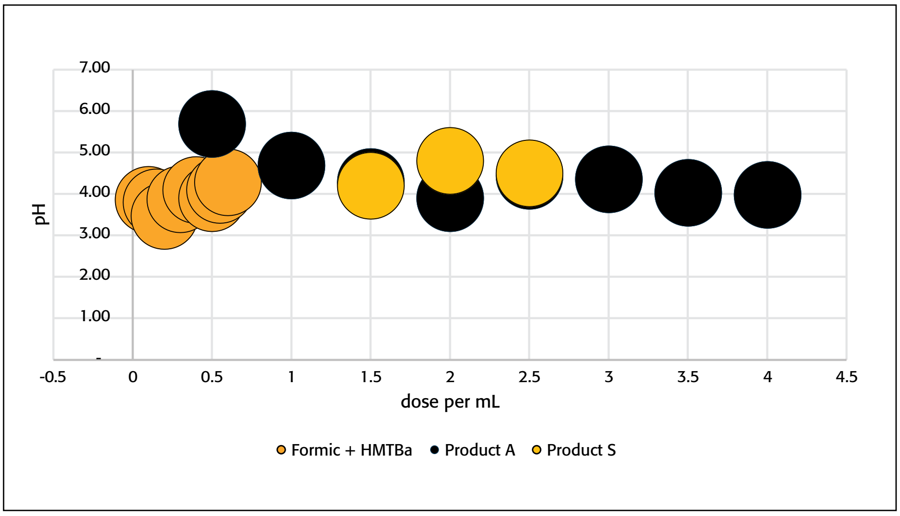


performed in a commercial lab in Australia wherein a titration test was done to determine how much dose was needed for the different product combinations to reduce the pH in water. Based on the results, it showed that the formic, propionic acid and HMTBa combination, lowers down the pH faster, at a much lower dosage as compared to other combinations (Figure 6).

Formic, acetic, ammonium formate (Product A); formic, lactic, butyric, sodium formate (Product B); lactic, phosphoric, citric, propionic, acetic acid (Product C); formic, propionic fumaric (Product D); propionic, ammonium propionate, formic, ammonium formate (Product E).

Another set of titration trials were done with water samples from Philippines, Indonesia, Malaysia and Vietnam, wherein a combination of formic, propionic acid and HMTBa was compared against commonly used organic acid combinations currently available in these markets. A total of 51 water samples with varying pH were taken from participating farms and were initially tested for current pH. The samples were then titrated with different organic acid combinations to determine the amount (dose) of organic acid combinations necessary to reduce the pH to a target between 3-4 (Figure 7). The results show that the formic, propionic acid and HMTBa combination needs less than 1 mL per liter of water to lower pH of water to 3-4 while the other acid combinations need around 1-4mL per liter of water to effectively lower the pH to the desired level. The lower dosages recorded for the formic, propionic acid and HMTBa combination may be due to the synergistic effect of formic and HMTBa as both are strong acids and are similar in their antibacterial effects.

Figure 7: Examining combinations of different organic acids: formic acid and HMTBa, citric acid and sorbic acid (Product A), formic acid and propionic acid and salts (Product S) on pH.



Conclusion

pH is an important factor that should be considered in both poultry and swine production. Aside from improving the water quality, paying particular attention to pH can also influence bacterial populations in the water and in the animal's gut, thus maintaining the balance of the gut environment. Water will be the critical nutrient in poultry and swine, as Southeast Asia goes toward AGP-free or antibiotic-free production to sustain growth and meet increasing demands by a growing population. *AP*

**Dr. Dexter Abrigo (Dexter.Abrigo@novusint.com) is Marketing Director, Novus Southeast Asia Pacific.*