



A Primer: Understanding Acids and the Acidification of Water

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The use of acids in poultry production today is very common as they have a wide variety of application, from acidification of water for perceived gut health benefits to the activation or potentiation of disinfection chemicals. There are just as many acid-based water treatment products available as there are diverse uses for them. However, understanding how these products behave in water and how the chemistry and the composition of the water on the farm can impact their overall efficacy is critical to success. This article is intended to briefly touch on the practical fundamentals of acid chemistry, what acids actually do in water, and things to keep in mind when administering acid-based products into the farm drinking water.

What is pH

In order to further understand acids and their useful behavior in water, we first need to have a good understanding of pH and what it means. To keep the definition of pH in simplest terms, it is a measurement of the concentration of hydrogen ions [H⁺] in an aqueous solution (for the purposes of this article, we will be referring to water).

This measurement can be described by the following equation:

$$\text{pH} = -\log [\text{H}^+] \text{ or } \text{pH} = -\log [\text{OH}^-]$$

The pH scale is generally presented with values that range from 0 to 14. Pure water has a pH value of 7, and any solution with a pH less than 7 (pH 7 to zero) is regarded as “acidic” and any solution with a pH greater than 7 (7 to 14) is regarded as alkaline, or “basic.” The pH scale is a logarithmic; on this scale, each whole number change results in a solution that is 10 times more acidic or basic.

Examples:

A pH value of 3 is 10 times more acidic than a pH value of 4, and a pH = 3 is 100 times (10 times 10) more acidic than a pH = 5.

The same relationship holds true with alkaline solutions:

A pH value of 11 is 10 times more alkaline than a pH value of 10, and a pH value of 11 is 100 times (10 times 10) more alkaline than a pH value of 8.

When acidifying water, the goal is to increase the concentration of hydrogen ions [H⁺] to create an excess of them in the water. This shifts the equilibrium of the water, resulting in a decrease in, or lowering of, the pH of the water.

Two key aspects to know about your acid choice

Acids can be classified or grouped together in a few different ways based on their chemical formulas, which is useful when you are choosing to buy and use one brand of acid over another. These classifications allow for an understanding of how acids react in water and lend insight on their ability to actually acidify farm drinking water.

It is important to have understanding of at least one of two interrelated values, and what they mean for acid impact on pH of drinking water; these two values are the 1) K_a and then the 2) pKa of each acid.

K_a is the acid disassociation constant; to keep it simple, K_a is the measure of an acid's strength when in solution. The larger the number, the stronger the acid. K_a values can often be hard to simply look at and compare between acids due to the fact they are often expressed in scientific notation. This is where the pKa value comes into play.

pKa is a more simple (and best) way to express the same value; the relationship is expressed by the equation below. When using pKa values, **the more negative the number, the stronger the acid.**

$$pKa = -\log(Ka)$$

Example:

Sulfuric Acid (H_2SO_4)

$$K_a = 1.0 \times 10^{-3} \text{ or } .001$$

$$pKa = -\log(1.0 \times 10^{-3}) = -3$$

(Using the pKa values makes it easier when comparing different acids and their strengths.)

Strong acids versus weak acids

The difference between strong and weak acids is their tendencies to disassociate or separate into a proton H^+ and an anion A^- in solution. The strength of an acid is quantified by its K_a and pKa value; strong acids are said to have a K_a value above 1 and a pKa value below 1 (recall the relationship above). Conversely, weak acids will have a K_a value below 1 and a pKa value above 1.

Strong acids completely disassociate in water and weak acids partially disassociate in water and remain in an

equilibrium. The extent of this equilibrium is dependent on the K_a and pKa values of the acid and the pH of the water. At a pH equal to the pKa value of the weak acid, the equilibrium will be at a ratio of 50% HA (associated) and 50% $H^+ + A^-$ (disassociated).

Common strong acids used on-farm:

Hydrochloric Acid – HCl (inorganic)

Sulfuric Acid – H_2SO_4 (inorganic)

Common weak acids used on-farm:

Acetic acid $C_2H_4O_2$ (vinegar; organic)

Propionic acid – $C_3H_6O_2$ (organic)

Citric acid – $C_6H_8O_7$ (organic)

Phosphoric acid – H_3PO_4 (inorganic)

Strong acid disassociation:



(The acid completely disassociates into a proton and an anion when added to the water.)

Weak acid disassociation:



(Both the acid molecule [associated form] and the proton and anion [disassociated form] exist in an equilibrium when added to the water.)

Monprotic (only one H^+) acids versus polyprotic (more than one H^+) acids

When adding acids to poultry or swine drinking water, the goal is to increase the hydrogen ion concentration of the water and, therefore, lower the pH. So the portion of the acid molecule we are most concerned with is the H^+ proton. Acids can again be classified in terms of how many potential hydrogen ions they are able to contribute to the water; an acid that is capable of donating a single hydrogen ion to the water is said to be monprotic (a single hydrogen H^+). Acids that are cable of donating more than one hydrogen ion to the water are said to be polyprotic (two or more free hydrogen protons). Polyprotic acids can be further classified on how many hydrogens they are able to donate.

For example, sulfuric acid is a diprotic (H_2A – two hydrogens H^+) acid; its chemical formula is H_2SO_4 . Therefore, it has the ability to donate up to two hydrogen ions.

Now if we take a look at phosphoric acid, which is actually a triprotic (H_3A – three hydrogen) acid, it has the ability to donate up to three hydrogen ions. However, just because an acid is composed with multiple hydrogen atoms does not mean it will always donate all of its hydrogen ions to the water. When polyprotic acids are added to the water, each disassociation has its own set of assigned K_a and corresponding pKa values. With each subsequent disassociation, these values increase and the disassociations become less favorable (or, more difficult to use more of the H^+ in that acid molecule). Let's take a look at both sulfuric acid and phosphoric acid to better understand this concept.

Examples:

Sulfuric Acid (diprotic): H_2SO_4

1st Disassociation: $H_2SO_4 \rightarrow H^+ + HSO_4^-$ pKa = -3
(strong acid)

2nd Disassociation: $HSO_4^- \leftrightarrow H^+ + SO_4^{2-}$ pKa = 1.92
(weak acid)

Sulfuric acid is a strong acid as shown by its pKa value of -3. But after the first disassociation, the pKa value of the remaining hydrogen sulfate ion is greater than 1 and, therefore, actually a weak acid in nature. Therefore, the extent of the second disassociation becomes specifically dependent on the pH of the water. (For all purposes of farm animal drinking water, the second disassociation will be near complete.) It's this relationship that makes sulfuric acid a good choice for acidification in already quite naturally low pH water situations.

Phosphoric Acid (triprotic): H_3PO_4

Looking at phosphoric acid and its disassociation in water (this is when the relationship of pKa and pH and how it affects disassociation comes into play).

1st Disassociation: $H_3PO_4 \leftrightarrow H^+ + H_2PO_4^-$ pKa = 2.12
(weak acid)

2nd Disassociation: $H_2PO_4^- \leftrightarrow H^+ + HPO_4^{2-}$ pKa = 7.21
(weak acid)

3rd Disassociation: $HPO_4^{2-} \leftrightarrow H^+ + PO_4^{3-}$ pKa = 12.31
(weak acid)

Phosphoric acid is a triprotic acid as it has the potential to donate three hydrogen protons to the water, but the extent of the disassociations, as it is a weak acid in nature, are dependent on the pH of the farm drinking water into which it is being added. The first disassociation will be near complete in nearly all the farm water it will be added to; in the field, however, when it comes to the second disassociation, phosphoric acid becomes a very poor acidifier due to the relationship between pH and pKa. The second disassociation pKa value for phosphoric acid is 7.21. From this, it is known that at a pH of 7.21, the equilibrium of $H_2PO_4^-$ and HPO_4^{2-} will be 50/50. Therefore, the amount of hydrogen protons that will be donated is limited to an additional 50%, and further reduction of pH will become very difficult unless large amounts of additional acid are added to supplement hydrogen protons generated from the first disassociation.

Organic acids versus inorganic acids (mineral acids)

The principal difference between organic vs inorganic acids is the presence of carbon in their chemical composition. Organic acids are not (necessarily) allowed any certification like OMRI—this organic acid designation is strictly technical, not for certified organic production of poultry or swine animals for slaughter. Simply put, organic acids contain carbon and inorganic acids do not. This will be important to keep in mind later in this article. Most of the strong acids used in the field will be inorganic acids, and the majority of the blended acid products will be organic blends that will also be weak acids.

Using acids on the farm

When using acid on the farm, regardless if the acid is being used to acidify water to improve water quality or for use in increasing the solubility of water-soluble products (i.e., antibiotics), it is important to know and understand how the water at the farm location will impact the efficacy of the products. And also how the addition of these products into the water can impact the status of the water system and the overall performance of the birds.

The chemical composition of the source water on farm can have a significant impact on the ability of acidifiers to lower the pH of the water. When adding acidifiers to farm water, the alkalinity and the hardness of the water needs

to be taken into consideration. The concentration of these analytes in the water will directly impact the degree of difficulty or ease the pH of the water might be adjusted.

For example: two different farm locations within close proximity to each other can have significantly different (i.e., low vs high alkalinity) water chemistry and a product that works well on one farm may not yield any significant results on the other. In general, the higher the alkalinity and hardness, the more difficult it is going to be to move the pH of the water due to increased buffering capacity—or “cancelling out” of the acid.

With simple test strips or an inexpensive water pH probe, onsite testing can be easily and quickly done with the desired acidifiers to measure the amount of product that needs to be added to achieve the desired pH range. To achieve best results, both the chemical composition of the native farm well water and the attributes of acidifier should be taken into consideration when selecting a brand/product.

Final considerations

Any time a product is added to the water that is ultimately going to be consumed by the birds, it is critical to have an understanding of what is being added and how it can impact the water system and the birds' performance. Earlier in this article, the difference between organic and inorganic acids was explained and that difference is the presence of carbon in the chemical composition of the acid. This difference does not seem that significant at first glance; however, carbon can be used as a food source by any microbiology that may be living on the inside of the entire water system (i.e., pressure regulators, pressure tanks, stand pipes, drinker lines). This potential food source, along with shifting of pH, can create the perfect environment for a “bio-bloom” on the inside of the waterlines, effectively plugging the waterlines and cutting off the water supply to the birds. Some reading this article may have already experienced this on your own farms.

When using organic acids, it is recommended to be continuously disinfecting the water or follow the use of organic acids with a biocidal molecule such as hypochlorous acid (tablet), acid-activated chlorine dioxide, an EPA-registered biocidal peroxide, or an EPA-registered peracetic acid to prevent this bloom from occurring. Using water

line disinfectants between each flock is critical when using organic acids/blends to simply adjust pH or provide optimal GI tract acidification for bird gut health.

The last piece to consider is the composition of the acid itself, and equally to consider the resulting anion(s) [A] remaining in the water, and the subsequent impact these can have on the birds. One example might be using a sulfuric acid-based product and the large amount of acid that may be required to reduce the pH to the desired range in highly buffered water. While rare, this approach can lead to a significant increase in the amount of sulfate ions present in the water. High levels of sulfates and the interaction with magnesium in the water can have a laxative effect on the birds, negatively impacting performance. This is just one example of many potential pitfalls and interactions that need to be taken into consideration when adding acidifiers or any product to the water on-farm.

Treating water is not hard, but you need to first know and understand your farm's drinking water chemistry and follow up by seeking good advice from a reputable technical supplier who will truly help (and not just sell you a “one-size-fits-all, one-product-can-do-it-all” silver-bullet approach). If you have questions related to acids and acidification of water, please reach out to your MWI Animal Health Territory Manager. We are happy to help!

References

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