PREPARATION METHOD AND APPLICATION OF WEAKLY ACIDIC CARBON DIOXIDE NANOBUBBLE WATER

Field of the Invention

The invention belongs to the technical field of food preservation, and particularly relates to a preparation method and application of weakly acidic carbon dioxide nanobubble water.

Background to the Invention

In the field of food preservation, weakly acidic carbon dioxide bubble water has been widely used in postharvest preservation of fruits and vegetables due to its antibacterial and preservation properties. In the existing technology, the preparation of weak acid carbon dioxide bubble water is mostly using ultrasonic cavitation, direct ventilation dissolved gas and other processes, through the introduction of carbon dioxide gas into the water body, with acid regulator to adjust the pH of the water body to the weak acid range, in order to obtain a fresh-keeping function of the bubble water. At the same time, in the application of fruit and vegetable preservation, the existing technology often uses atomized spray, soaking and other ways to apply bubble water to postharvest fruits and vegetables, and then combined with low-temperature storage to achieve the extension of the preservation cycle. In addition, in the prior art, food-grade raw materials have been gradually used to prepare bubble water to ensure product safety, and related preparation equipment such as ultrasonic generators and ventilation devices have also been industrialized, providing basic support for large-scale production and preservation applications of bubble water.

Although the existing technology has realized the preparation and preservation application of weakly acidic carbon dioxide bubble water, there are still many shortcomings in combination with the actual application requirements. In the preparation process, the existing processes mostly rely on a single physical treatment method, lack of multi-process collaborative design, and are difficult to stably generate nano-scale bubbles. In addition, the pH adjustment method of directly adding acid agent is often adopted, which easily leads to pH fluctuation and cannot ensure the uniformity of product performance. At the same time, the existing processes generally lack end-stabilizing and balanced treatment, and the bubble concentration decays rapidly, thus greatly shortening the effective shelf life of the product. In the application of preservation, the existing bubble water is difficult to effectively inhibit the decay of fruits and vegetables through synergy due to poor bubble stability and inaccurate regulation of weak acid environment, and the preservation effect is limited. In addition, some of the existing preparation processes are demanding on equipment or have poor parameter adaptation, making it difficult to flexibly adapt to different scale production scenarios, resulting in obstacles to large-scale promotion and unable to fully meet the needs of the green and efficient fruit and vegetable preservation industry.

Statement of Invention

In order to overcome the above-mentioned defects of the prior art, the present invention provides a preparation method and application of weakly acidic carbon dioxide nanobubble water, and solves the problems of many defects in the preparation process of weakly acidic CO_2 bubble water in the prior art, and the preservation effect is poor and difficult to scale.

To achieve the above objectives, the present invention provides the following technical solutions:

A preparation method and application of weakly acidic carbon dioxide nanobubble water, comprising the following steps:

S1: The first stage of micro-jet treatment, the pure water and food-grade carbonate mixed into the micro-jet module, by high-pressure shear to form 1-10μm micron-sized bubble precursor;

S2: The second stage of ultrasonic cavitation treatment is to introduce the water body containing micron-sized bubble precursors obtained by S1 into the ultrasonic cavitation module, introduce high-purity carbon dioxide and add pH slow-release microcapsules, carry out cavitation reaction in the ultrasonic field, so that the pH of the water body slowly transitions from initial neutral to 5.5-6.0 to obtain an intermediate water body containing nano-bubbles; The shell material of the pH slow-release microcapsules is pectin-sodium alginate composite membrane, the core material is a mixed acid of citric acid and malic acid;

S3: terminal gas-liquid equilibrium pressure stabilization treatment, introducing the intermediate water body obtained by S2 into a gas-liquid equilibrium pressure stabilization tank, maintaining a micro-positive pressure environment of 0.8-1.0MPa in the tank, and obtaining weak acid carbon dioxide nanobubble water after standing at a constant temperature of 20-25 ℃; The nanobubble particle size of the weakly acidic carbon dioxide nanobubble water is 50-200nm, the Zeta potential is-30mV to-40mV, and the 24h bubble concentration attenuation rate is lower than 8%.

Preferably, the food grade carbonate in S1 is sodium bicarbonate, and the addition amount of sodium bicarbonate in purified water is 0.05-0.1g/L.

Preferably, the pressure of high-pressure shearing in S1 is 80-120MPa, the treatment temperature is 20-30 ° C., and the treatment time is 3-5min.

Preferably, the purity of the high-purity carbon dioxide in S2 is not less than 99.9, the introduction rate is 0.5-1.0L/min, and the volume ratio of the introduction amount to the water body is 1:5-1:10.

Preferably, the ultrasonic frequency of the ultrasonic field in S2 is 20-40kHz, the ultrasonic power is 300-500W, and the ultrasonic treatment time is 10-15min.

Preferably, the particle size of the pH slow-release microcapsule in S2 is 100-200 μm, the mass ratio of pectin to sodium alginate in the shell material is 1:2-2:1, the mass ratio of citric acid to malic acid in the core material is 1:1-3:1, and the addition amount of the microcapsule is 0.01-0.03 of the water body mass.

Preferably, the temperature of the constant temperature standing in S3 is 20-25 DEG C, and the standing time is 20-30min.

Preferably, the conductivity of the purified water in S1 is not more than 10 μS/cm, and the total hardness is not more than 5mg/L calculated as calcium carbonate.

Preferably, the micro-jet module used in S1 includes a high-pressure pump and a diamond interaction cavity, and the aperture of the diamond interaction cavity is 0.1-0.3mm; The ultrasonic cavitation module used in S2 includes an ultrasonic generator and a reaction kettle, a gas distributor is arranged in the reaction kettle, and the pore diameter of the gas distributor is 50-100 μm.

Preferably, an application of weakly acidic carbon dioxide nano-bubble water is as follows: the prepared weakly acidic carbon dioxide nano-bubble water is used to atomize and spray postharvest fruits and vegetables, the spray time is 10-15min, and the fruits and vegetables are stored in an environment of 0-4 ° C. after spraying.

The invention provides a preparation method of weakly acidic carbon dioxide nanobubble water and technical effects and advantages of the application:

1. The invention solves the technical problem that it is difficult to generate stable nanobubbles by traditional single physical treatment through the collaborative process design of two-stage microjet, pH slow-release microcapsules and gas-liquid balance stabilization. The combination of two-stage physical treatment and chemical regulation can not only refine bubbles efficiently, but also provide favorable conditions for the formation and stability of nanobubbles through the connection optimization of multi-stage process, which greatly improves the stability and controllability of nanobubble preparation compared with the traditional process.

2, the invention uses pH slow-release microcapsules instead of the traditional direct acid-adding method, to achieve a slow and accurate transition of water pH from the initial neutral to the target weak acid range. The design effectively avoids the problem of pH fluctuation caused by direct acid addition, and ensures that the pH value of the finally prepared weakly acidic carbon dioxide nanobubble water is stable in a suitable range, thus ensuring the uniformity of product performance and laying a foundation for the stability of subsequent application effects.

3, the invention by means of the end treatment process of gas-liquid balance pressure stabilization, with the early two-stage treatment and pH precise control, the carbon dioxide nanobubbles prepared by the present invention have extremely strong stability, can effectively reduce the bubble concentration attenuation rate. This advantage not only extends the effective shelf life of nanobubble water, but also ensures that it continues to play the unique effect of nanobubbles in the application process, and enhances the practical application value of the product.

4. When the weakly acidic carbon dioxide nanobubble water prepared by the invention is applied to the postharvest preservation of fruits and vegetables, the characteristics of nanobubbles and the synergy of the weakly acidic environment can effectively inhibit the decay of fruits and vegetables and prolong the preservation period. The whole preservation process does not need to add chemical preservatives, which meets the current development needs of green and safe food preservation and has broad industrial application prospects.

5, the invention of the preparation process parameters range is reasonable, each processing module can be flexibly adjusted according to the actual production needs, adapt to different scales of production scenarios. At the same time, the raw materials used are food grade, the equipment is conventional industrial grade, no special high-end equipment is needed, which reduces the threshold of large-scale production and facilitates the popularization and application of technology.

Brief Description of the Drawings

Figure 1 is a flow chart of a preparation method and application of weakly acidic carbon dioxide nanobubble water according to the present invention.

Detailed Description

The following clearly and completely describes the technical solutions in the embodiments of the present invention with reference to the accompanying drawings in the embodiments of the present invention. Apparently, the described embodiments are only a part of the embodiments of the present invention, rather than all of the embodiments.

It should be noted that in this article, relational terms such as first and second are only used to distinguish one entity or operation from another entity or operation, and do not necessarily require or imply that these entities or operations have any actual relationship or order. Moreover, the terms include, include or any other variation thereof are intended to cover non-exclusive inclusions, so that a process, method, article or apparatus comprising a series of elements includes not only those elements, but also other elements not explicitly listed, or elements inherent to such a process, method, article or apparatus, in the absence of more restrictions, the elements defined by the sentence including, it does not preclude the presence of additional identical elements in a process, method, article, or apparatus that includes the elements.

1, the present invention discloses a preparation method and application of weakly acidic carbon dioxide nanobubble water, which aims to solve the pain point of the prior art in the field of food preservation. The preparation method adopts the collaborative process of "two-stage microjet + ultrasonic cavitation + gas-liquid equilibrium pressure stabilization". First, purified water and food-grade sodium bicarbonate are mixed and then introduced into the microjet module, and then subjected to high-pressure shearing at 80-120MPa to form 1-10μm micron bubble precursor. Then the ultrasonic cavitation module is introduced, carbon dioxide with purity ≥ 99.9 is introduced, pH slow-release microcapsules (particle size 100-200μm) are added, and processed in 20-40kHz for 10-15min; finally, after 0.8-1.0MPa micro positive pressure constant temperature static 20-30min, the particle size of 50-200nm, 24h attenuation rate of less than 8% of the nano bubble water. In terms of application, the bubble water is used to spray the postharvest fruits and vegetables for 10-15min, and the low temperature storage of 0-4 ℃ is used to achieve fresh-keeping. Through multi-process coordination and precise regulation, this scheme solves the problems of poor bubble stability, pH fluctuation and limited preservation effect of the existing technology, and has strong adaptability of process parameters, which can be promoted on a large scale to meet the needs of green and efficient fruit and vegetable preservation.

The raw materials used in the following examples are commercially available food grade raw materials, the equipment is conventional industrial grade equipment, the detection method is as follows:

1. Nano bubble size and Zeta potential: using nano particle size analyzer (model: Malvern ZetasizerNanoZS90) detection;

2.24-hour bubble concentration attenuation rate: the bubble concentration of finished product water standing for 0h and 24h is detected by nano-bubble concentration meter (model: MLS-6000) respectively, and the attenuation rate is calculated =(0h concentration

-24h concentration)/0h concentration × 100%;

3. Fresh-keeping effect of fruits and vegetables: taking strawberries as the test object, 50 strawberries with uniform size and no damage were selected in each group, and the decay rate of 5 days and 10 days of storage was counted. The decay rate = the number of rotten strawberries/the total number × 100%.

Example 1

Implementation purpose:

To verify the stability of weak acid carbon dioxide nanobubble water prepared by the two-stage microjet, pH slow-release microcapsules, and the application effect of the nanobubble water in the preservation of fruits and vegetables under the condition of conventional parameters.

Raw material preparation:

Purified water with a conductivity of 8 μS/cm and a total hardness of 3mg/L (calculated as CaCO) was selected. Food grade sodium bicarbonate; High purity carbon dioxide (purity 99.92); PH slow-release microcapsules (particle size 150 μm, mass ratio of shell pectin to sodium alginate 1:1, mass ratio of core citric acid to malic acid 1:1).

Implementation steps:

S1: In the first stage of microjet treatment, pure water and sodium bicarbonate are mixed (with an addition amount of 0.07g/L), passed into a microjet module (including a high-pressure pump and a diamond interactive cavity with an aperture of 0.2mm), and subjected to high-pressure shearing for 4min at a pressure of 80MPa and a temperature of 25 ℃ to form a 5μm micron bubble precursor;

S2: the second stage of ultrasonic cavitation treatment, the water body obtained by S1 is introduced into the ultrasonic cavitation module (including ultrasonic generator and reactor, the pore diameter of the gas distributor in the reactor is 80μm m), high purity carbon dioxide is introduced at a rate of 0.7L/min (the ratio of the introduced volume to the water body volume is 1:7), and pH slow-release microcapsules with 0.02 water body mass are added at the same time, and ultrasonic treatment is 12min under the conditions of 30kHz and 400W, slow transition of water pH from initial neutral to 5.8;

S3: end gas-liquid equilibrium pressure stabilization treatment, the intermediate water body obtained by S2 is introduced into the gas-liquid equilibrium pressure stabilization tank, the micro-positive pressure environment of 0.9MPa in the tank is maintained, and the water is kept at a constant temperature of 22 ℃ for 25min to obtain weak acid carbon dioxide nanobubble water.

Implementation effect:

The prepared weakly acidic carbon dioxide nano-bubble water has a nano-bubble particle size of 120nm,Zeta potential of-35mV,24-hour bubble concentration attenuation rate of 6.2, and has excellent nano-bubble stability. The postharvest strawberry was atomized and sprayed for 12min. After spraying, the strawberry was stored in an environment of 2 ℃. The decay rate was 3.2 for 5 days and 8.5 for 10 days. The preservation effect was remarkable.

Example 2

Implementation purpose:

Under the condition of lower parameters, the feasibility of the preparation process of the present invention and the effect of the product applied to the preservation of fruits and vegetables are verified, and the suitability of the lower limit of the process parameters is clarified.

Raw material preparation:

Purified water with a conductivity of 5 μS/cm and a total hardness of 2mg/L (calculated as CaCO) was selected. Food grade sodium bicarbonate; High purity carbon dioxide (purity 99.95);pH slow-release microcapsules (particle size 100 μm, mass ratio of shell pectin to sodium alginate 1:2, mass ratio of core citric acid to malic acid 2:1).

Implementation steps:

S1: The first stage of microjet treatment is to mix purified water with sodium bicarbonate (the addition amount is 0.05g/L), pass into the microjet module (the aperture of the diamond interaction cavity is 0.1mm), and shear at high pressure for 3min under the conditions of

100MPa and 20 ℃ to form a 1μm micron bubble precursor;

S2: the second stage of ultrasonic cavitation treatment, the water body obtained by S1 is introduced into the ultrasonic cavitation module (the diameter of the pores of the gas distributor is 50μm), high-purity carbon dioxide is introduced at a rate of 0.5L/min (the ratio of the introduced volume to the water body volume is 1:5), and pH slow-release microcapsules with 0.01% of the water body mass are added at the same time, and ultrasonic treatment is carried out for 10min under the conditions of 20kHz and 300W, slow transition of water pH from initial neutral to 5.5;

S3: end gas-liquid equilibrium pressure stabilization treatment, the intermediate water body obtained by S2 is introduced into the gas-liquid equilibrium pressure stabilization tank, the micro-positive pressure environment of 0.8MPa in the tank is maintained, and the water is kept at a constant temperature of 20 ℃ for 20min to obtain weak acid carbon dioxide nanobubble water.

Implementation effect:

The prepared weakly acidic carbon dioxide nano-bubble water has a nano-bubble particle size of 50nm,Zeta potential of-38mV,24-hour bubble concentration attenuation rate of 5.1, and excellent stability. The postharvest strawberry was atomized and sprayed for 10min, and stored in a 0 ℃ environment after spraying. The decay rate was 2.8 in 5 days and 7.2 in 10 days, good preparation effect and preservation effect can still be achieved under low parameter conditions.

Example 3

Implementation purpose:

Under the condition of higher parameters, the reliability of the preparation process of the present invention and the application effect of product preservation are verified, and the applicability of the upper limit of the process parameters is clarified.

Raw material preparation:

Purified water with a conductivity of 10 μS/cm and a total hardness of 5mg/L (calculated by CaCO) was selected. Food grade sodium bicarbonate; High purity carbon dioxide (purity

99.9);pH slow-release microcapsules (particle size 200 μm, mass ratio of shell pectin to sodium alginate 2:1, mass ratio of core citric acid to malic acid 3:1).

Implementation steps:

S1: The first stage of microjet treatment is to mix purified water with sodium bicarbonate (the addition amount is 0.1g/L), pass into the microjet module (the aperture of the diamond interaction cavity is 0.3mm), and shear at high pressure for 5min under the conditions of 120MPa and 30 ℃ to form a 10μm micron bubble precursor;

S2: the second stage of ultrasonic cavitation treatment, the water body obtained by S1 is introduced into the ultrasonic cavitation module (the diameter of the pores of the gas distributor is 100 μm), high-purity carbon dioxide is introduced at a rate of 1.0L/min (the ratio of the introduced volume to the water body volume is 1:10), and pH slow-release microcapsules with 0.03 of the water body mass are added at the same time, and ultrasonic treatment is carried out for 15min under the conditions of 40kHz and 500W, slow transition of water pH from initial neutral to 6.0;

S3: end gas-liquid equilibrium pressure stabilization treatment, the intermediate water body obtained by S2 is introduced into the gas-liquid equilibrium pressure stabilization tank, the micro-positive pressure environment of 1.0MPa in the tank is maintained, and the temperature is kept at 25 ℃ for 30min to obtain weak acid carbon dioxide nanobubble water.

Implementation effect:

The prepared weakly acidic carbon dioxide nano-bubble water has a nano-bubble particle size of 200nm,Zeta potential of-32mV, and a 24-hour bubble concentration attenuation rate of 7.8, which meets the requirements of high stability. The postharvest strawberries were atomized and sprayed for 15min. After spraying, they were stored in an environment of 4 ℃. The decay rate was 4.5 for 5 days, 9.8 for 10 days, and the process was stable under high parameter conditions, the preservation effect is up to standard.

Example 4

Implementation purpose:

Under the condition of verifying the combination of medium and low parameters, the coordination of the preparation process of the present invention and the application effect of the product provide a basis for the flexible selection of process parameters.

Implementation steps:

S1: The first stage of microjet treatment is to mix purified water with sodium bicarbonate (the addition amount is 0.06g/L), pass into the microjet module (the aperture of the diamond interaction cavity is 0.15mm), and shear at high pressure for 3.5min under the conditions of pressure 90MPa and temperature 22 ℃ to form a 3μm micron bubble precursor;

S2: the second stage of ultrasonic cavitation treatment, the water body obtained by S1 is introduced into the ultrasonic cavitation module (the diameter of the pores of the gas distributor is 60μm), high-purity carbon dioxide is introduced at a rate of 0.6L/min (the ratio of the introduced volume to the water body volume is 1:6), and pH slow-release microcapsules with 0.015 of the water body mass are added at the same time, and ultrasonic treatment is carried out for 11min under the conditions of 25kHz and 350W, slow transition of water pH from initial neutral to 5.6;

S3: end gas-liquid equilibrium pressure stabilization treatment, the intermediate water body obtained by S2 is introduced into the gas-liquid equilibrium pressure stabilization tank, the micro-positive pressure environment of 0.85MPa in the tank is maintained, and the water is allowed to stand at a constant temperature of 21 ℃ for 22min to obtain weak acid carbon dioxide nanobubble water.

Implementation effect:

The prepared weakly acidic carbon dioxide nano-bubble water has a nano-bubble particle size of 80nm,Zeta potential of-36mV,24-hour bubble concentration attenuation rate of 5.7, and good stability. The postharvest strawberry was atomized and sprayed for 11min. After spraying, the strawberry was stored in an environment of 1 ℃. The decay rate was 3.0 in 5 days and 7.9 in 10 days. The combination of medium and low parameters had good coordination and excellent preparation and application effects.

Example 5

Implementation purpose:

Under the condition of verifying the combination of high and high parameters, the suitability of the preparation process of the present invention and the preservation effect of the product are used to broaden the application range of the process parameters.

Raw material preparation:

Purified water with a conductivity of 9 μS/cm and a total hardness of 3.5mg/L (calculated as CaCO) was selected. Food grade sodium bicarbonate; High purity carbon dioxide (purity 99.94);pH sustained-release microcapsules (particle size 180 μm, mass ratio of shell pectin to sodium alginate 1.5:1, mass ratio of core citric acid to malic acid 2.5:1).

Implementation steps:

S1: The first stage of micro-jet treatment is to mix purified water with sodium bicarbonate (the addition amount is 0.09g/L), pass into the micro-jet module (the aperture of the diamond interaction cavity is 0.25mm), and shear at high pressure for 4.5min under the conditions of 110MPa and 28 ℃ to form 8μm micron bubble precursor;

S2: the second stage of ultrasonic cavitation treatment, the water body obtained by S1 is introduced into the ultrasonic cavitation module (the diameter of the pores of the gas distributor is 90μm), high-purity carbon dioxide is introduced at a rate of 0.9L/min (the ratio of the introduced volume to the water body volume is 1:9), and pH slow-release microcapsules with 0.025% of the water body mass are added at the same time, and ultrasonic treatment is carried out for 14min under the conditions of 35kHz and 450W, slow transition of water pH from initial neutral to 5.9;

S3: end gas-liquid equilibrium pressure stabilization treatment, the intermediate water body obtained by S2 is introduced into the gas-liquid equilibrium pressure stabilization tank, the micro-positive pressure environment of 0.95MPa in the tank is maintained, and the water is allowed to stand at a constant temperature of 24 ℃ for 28min to obtain weak acid carbon dioxide nanobubble water.

Implementation effect: the prepared weakly acidic carbon dioxide nano-bubble water has a nano-bubble particle size of 180nm,Zeta potential of-33mV,24-hour bubble concentration attenuation rate of 7.1, and its stability reaches the standard. The postharvest strawberry was atomized and sprayed for 14min. After spraying, it was stored in a 3 ℃ environment. The decay rate was 4.1 for 5 days, 9.2 for 10 days, and the combination of medium and high parameters was well adapted, it can meet different production needs.

Proportion 1

Preparation of weak acid carbon dioxide bubble water by traditional process:

Implementation purpose:

The superiority of the two-stage microjet and pH slow-release microcapsules and gas-liquid balance stabilization synergistic process of the present invention is verified by comparison, and the deficiency of the traditional process is clarified.

Raw material preparation:

The same purified water, food grade sodium bicarbonate, high purity carbon dioxide, and citric acid as in Example 1 (no pH slow-release microcapsules, citric acid was directly used to adjust the pH).

Implementation steps:

Pure water is mixed with sodium bicarbonate (the addition amount is 0.07g/L), high-purity carbon dioxide is directly introduced (the injection parameters are consistent with those in Example 1), and citric acid solution is directly added dropwise to adjust the pH to 5.8. Traditional weakly acidic carbon dioxide bubble water is obtained only by single ultrasonic treatment (the parameters are consistent with those in Example 1), no micro-jet treatment and terminal gas-liquid equilibrium pressure stabilization treatment.

Implementation effect:

The prepared traditional weakly acidic carbon dioxide bubble water has a bubble size of 300-500nm (no nano bubbles),Zeta potential of-20mV, a 24-hour bubble concentration attenuation rate of 35.6, and extremely poor stability. The postharvest strawberries are atomized and stored under the same conditions. The decay rate in 5 days of storage is 15.3, the decay rate in 10 days of storage is 32.7, and the preservation effect is far lower than that of the products prepared by the process of the present invention, the innovation and superiority of the process of the present invention are confirmed.

Comparative Analysis of Example and Comparative Proportion Effect

It can be seen from the above embodiments 1-5 that the present invention can prepare weakly acidic carbon dioxide nanobubble water with high stability through the synergistic process of two-stage microjet + pH slow-release microcapsule + gas-liquid equilibrium pressure stabilization. The nanobubble particle size is 50-200nm, Zeta potential is -30 ~-40mV, and the 24-hour bubble concentration attenuation rate is less than 8%. All performance indexes are excellent, which proves that the preparation method of the present invention is stable and reliable and the parameter range is reasonable, adapt to different parameter combination requirements.

Compared with the comparative example, it can be seen that the traditional process cannot form stable nanobubbles due to the lack of two-stage micro-jet treatment, and the direct addition of acid leads to large fluctuation in pH control and extremely poor bubble stability (24-hour attenuation rate exceeds 30%); However, the present invention realizes accurate and slow pH control through pH sustained-release microcapsules, and significantly improves the stability of nanobubbles with two-stage physical treatment and pressure stabilization balance. In the application effect, the nano-bubble water prepared by the present invention can extend the strawberry preservation period to 7-10 days, and the decay rate is significantly lower than the traditional process, which fully confirms the effectiveness and superiority of the preparation process and application scheme of the present invention.

Examples 1-5 cover different parameter gradients, including raw material indicators, process pressure, temperature, time, microcapsule parameters, etc., which can achieve the expected preparation effect and preservation effect, and further prove the universality and reliability of the technical scheme of the present invention.

Compared with embodiment 1-5 and comparison 1, the present invention is based on the experimental data of embodiment 1-5 (the process of the present invention) and the comparison (traditional process), from the preparation process, product performance, fruit and vegetable preservation application effect three aspects of comparison, clear the advantages of the technical scheme of the present invention, as follows:

In the preparation process, Examples 1-5 all adopt a two-stage microjet + pH slow-release microcapsule + gas-liquid equilibrium pressure stabilization synergistic process, and realize the stable generation of nanobubbles through the combination of multi-stage physical treatment and precise pH control. The parameters cover five gradients of conventional, low, high, medium-low and medium-high, in which the microjet pressure is 80-120MPa, the ultrasonic frequency is 20-40kHz, and the gas-liquid equilibrium pressure is 0.8-1.0MPa, the addition amount of pH slow-release microcapsules is 0.01-0.03%, which is suitable for different production needs. The proportion of the traditional single ultrasonic process, no micro-jet pretreatment and end pressure stabilization steps, and directly add citric acid to adjust pH, no slow release control mechanism, simple process but poor controllability.

Significant differences in product performance. The weakly acidic carbon dioxide nanobubble water prepared in Examples 1-5 has a particle size in the range of 50-200nm nanometers, a Zeta potential of -30 ~-40mV, a 24-hour bubble concentration attenuation rate of less than 8% (minimum 5.1%, maximum 7.8%), and has excellent stability. In addition, the pH of water body can be accurately controlled to the weak acid range of 5.5-6.0 through pH slow-release microcapsules. The comparative product has no nanoscale bubbles, the bubble particle size is only 300-500nm, the Zeta potential is only-20mV, the 24-hour bubble concentration attenuation rate is as high as 35.6, the stability is extremely poor, and the direct addition of acid is easy to cause pH fluctuation and the control accuracy is insufficient.

In the application effect of strawberry preservation after harvest, the preservation advantages of Examples 1-5 are outstanding. After the same atomized spray treatment, under the storage conditions of 0-4 degrees C, the example group storage 5 days decay rate of 2.8-4.5, storage 10 days decay rate of 7.2-9.8, of which the low parameter group (embodiment 2) preservation effect is the best, 10 days decay rate of only 7.2. Under the same storage conditions, the 5-day decay rate reached 15.3%, and the 10-day decay rate soared to 32.7%, and the preservation effect was much lower than that of the example group.

In summary, the embodiment 1-5 verifies the stability and universality of the process of the present invention, through the collaborative process to achieve the high stability of nanobubbles and pH precision control, and thus significantly improve the preservation effect of fruits and vegetables. The process parameter gradient of the invention covers a comprehensive range, adapts to different production scenarios, and the preparation of weak acidic carbon dioxide nanobubble water has significant advantages in stability and preservation performance, and the technical scheme is innovative and practical.

The above descriptions are only specific embodiments of the present application, but the protection scope of the present application is not limited thereto. Any change or replacement that can be easily thought of by a person skilled in the art within the technical scope disclosed in the present application shall be covered by the protection scope of the present application. Therefore, the protection scope of the present application shall be subject to the protection scope of the claims.

Finally, the above description is only a preferred embodiment of the present invention, and is not intended to limit the present invention. Any modification, equivalent replacement, improvement and the like made within the spirit and principle of the present invention should be included in the protection scope of the present invention.