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(54) **AGING OF ALCOHOLIC BEVERAGES USING CONTROLLED MECHANICALLY INDUCED CAVITATION**

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(57) **ABSTRACT**

An extreme acceleration of the process of aging spirits to obtain aged liquors includes circulating the spirits through a cavitation zone within a controlled cavitation reactor and exposing the spirits therein to high energy cavitation induced shockwaves. Sources of flavor and color such as charred wood chips may be added to the spirits to provide the color and flavor of liquors aged for years in traditional charred oak barrels. The method and apparatus of the present invention obtains the same conversion of undesirable alcohols, flavor extraction, and color as years of aging in an oak barrel but does so in a matter of minutes or hours. The apparatus and method also can be used in conjunction with traditional aging techniques and methods and the total aging time is still reduced dramatically.

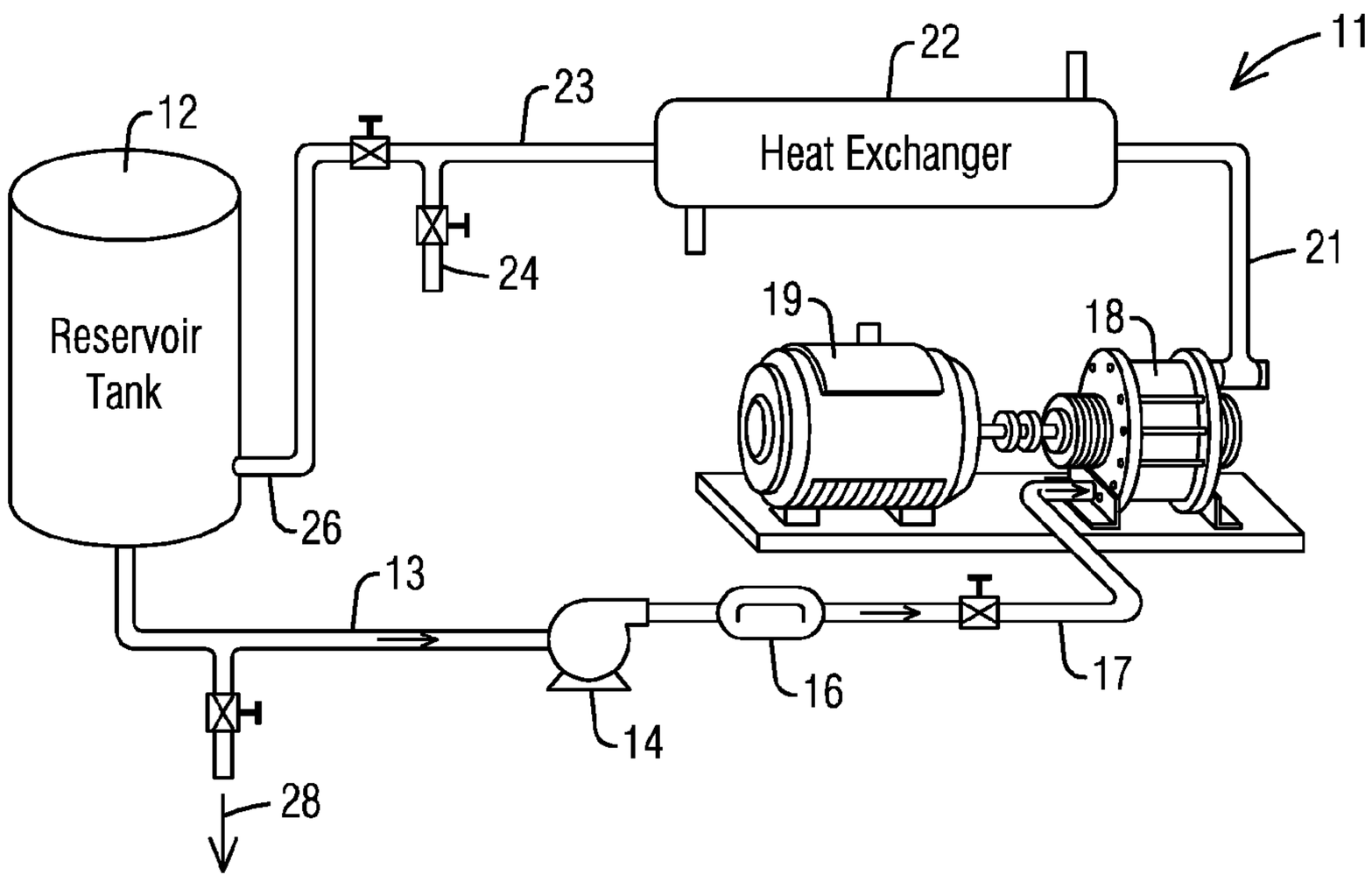


FIG. 1

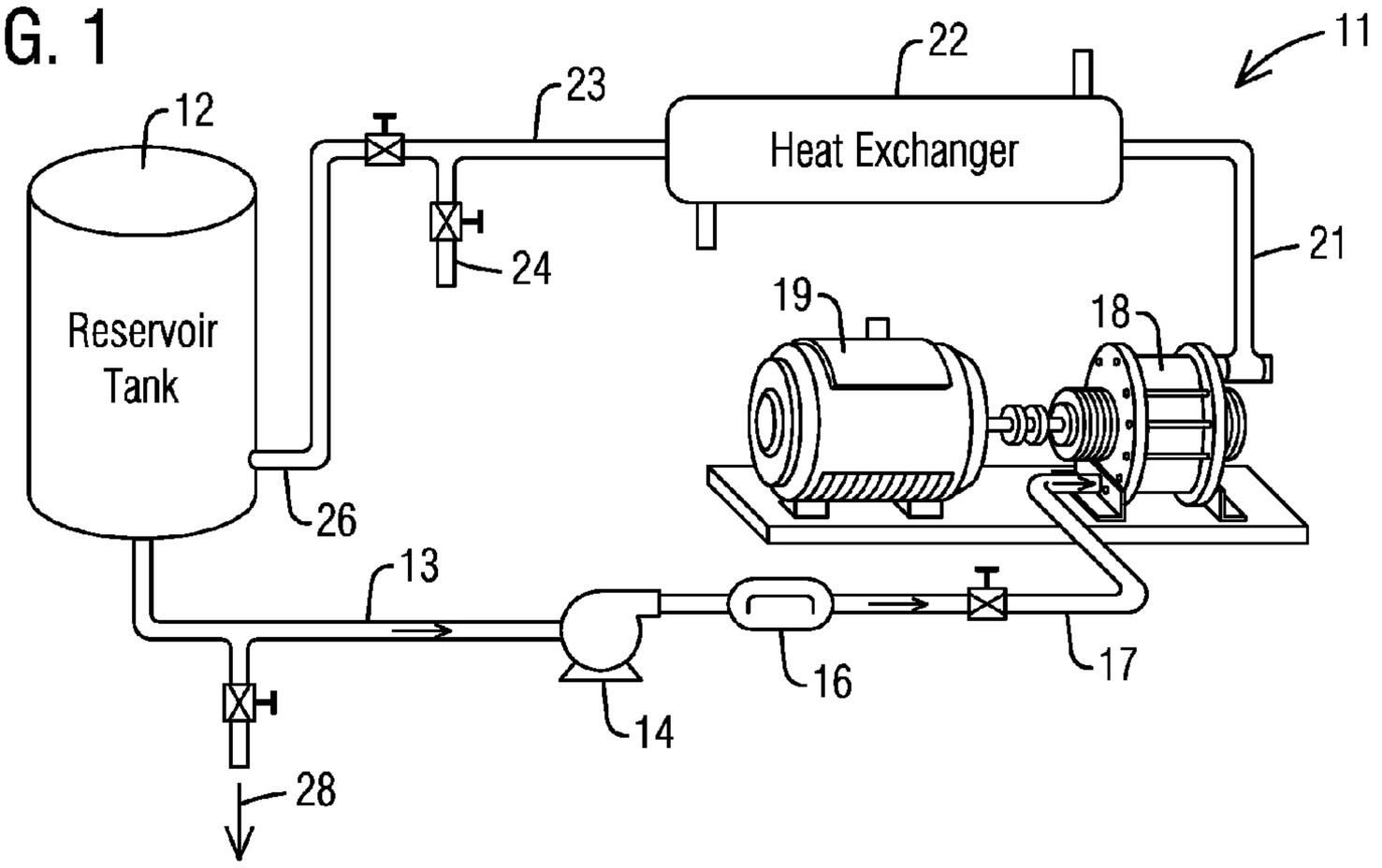

11
22
23
12
Heat Exchanger
21
24
19
18
Reservoir Tank
26
13
16
17
14
28

FIG. 2

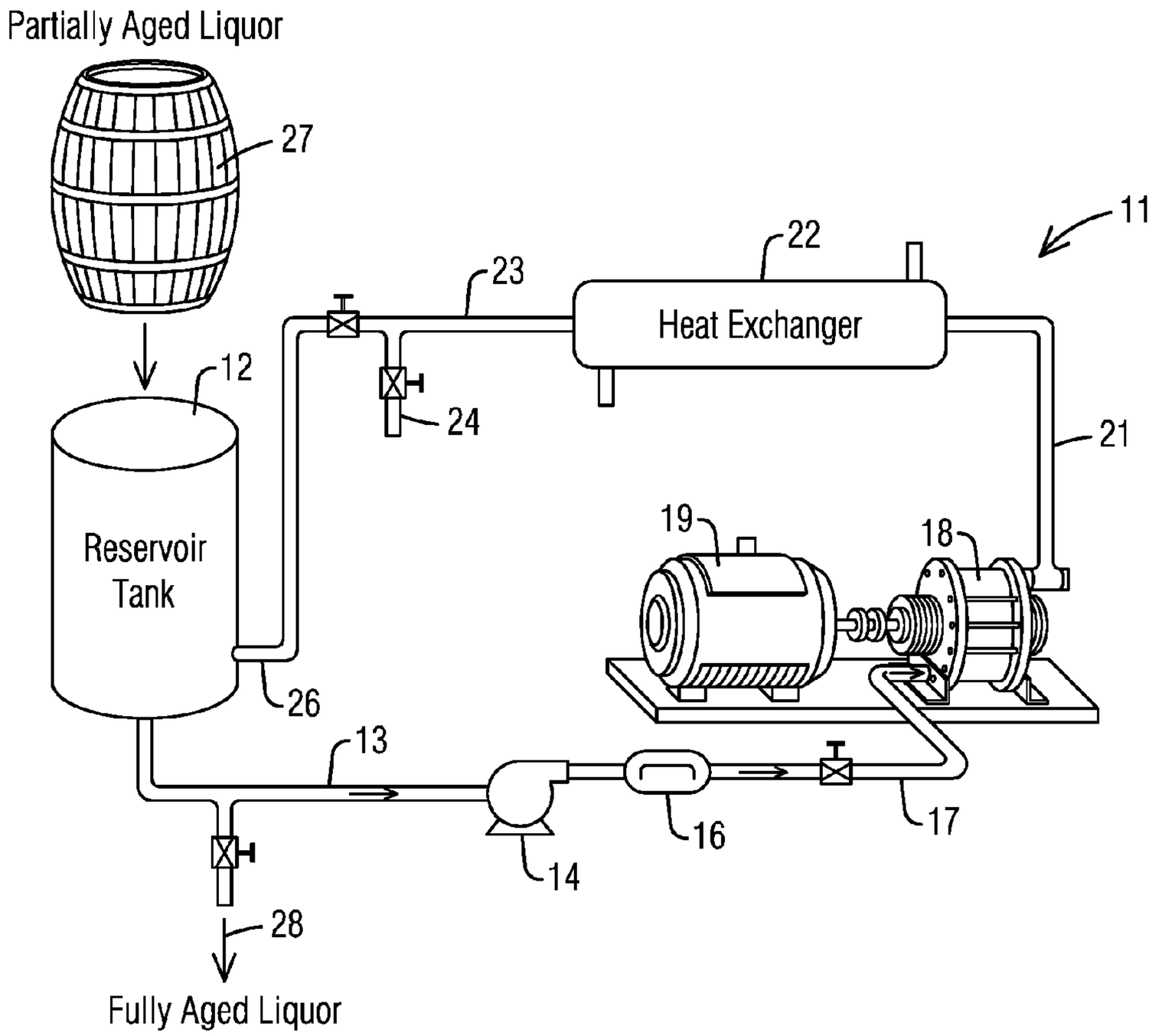
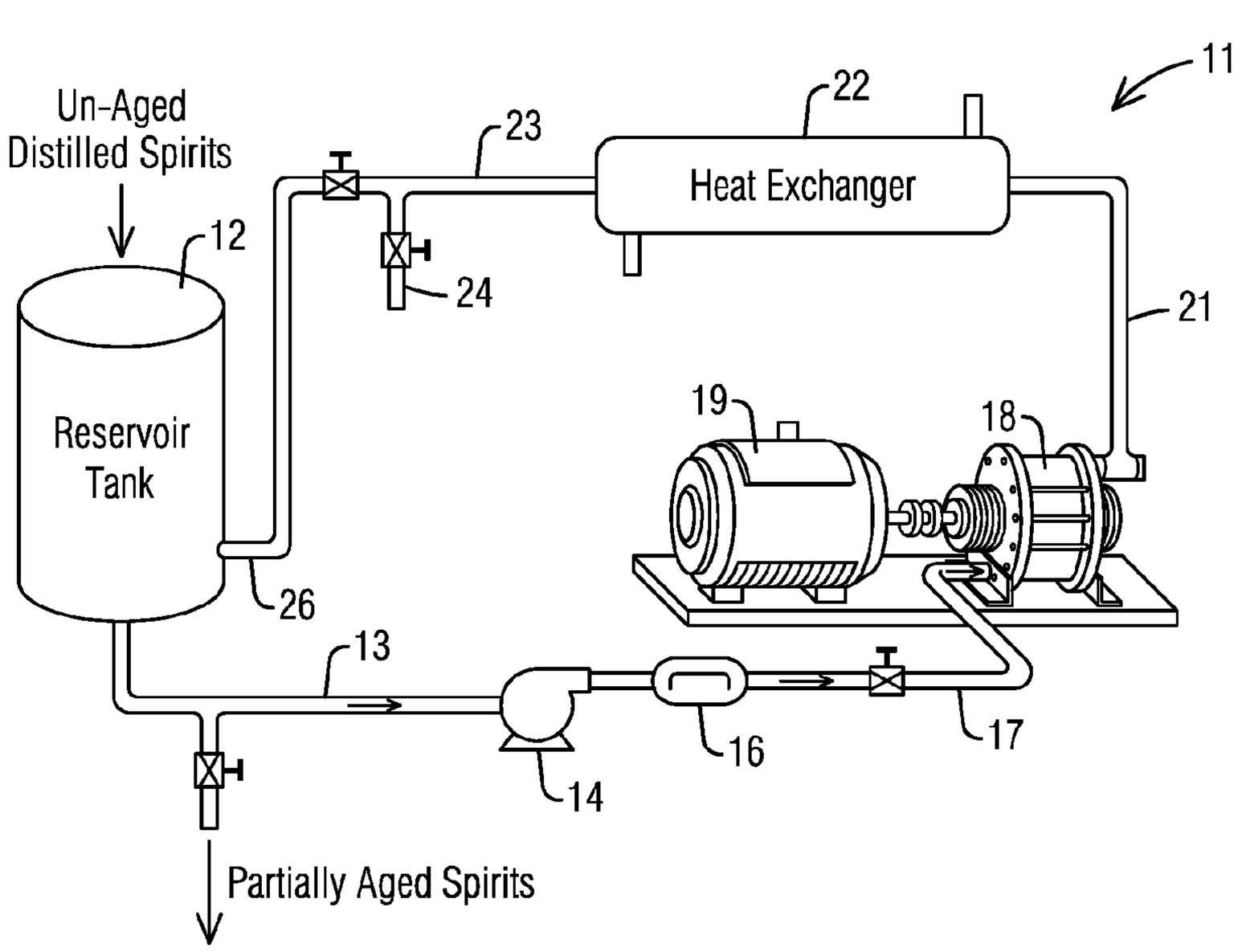
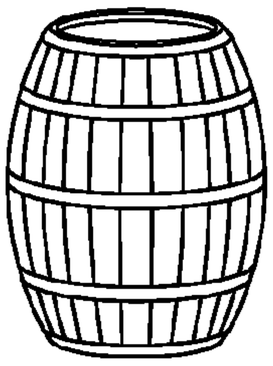

Partially Aged Liquor
27
11
22
23
12
Heat Exchanger
24
21
19
18
Reservoir Tank
26
13
16
17
14
28
Fully Aged Liquor

FIG. 3





Traditional Aging for
Specified Time

AGING OF ALCOHOLIC BEVERAGES USING CONTROLLED MECHANICALLY INDUCED CAVITATION

REFERENCE TO RELATED APPLICATION

[0001] Priority is hereby claimed to the filing date of U.S. provisional patent application 62/141,595 filed on Apr. 1, 2015 and to the filing date of U.S. provisional patent application 62/293,069 filed on Feb. 9, 2016. The contents of these provisional patent applications are hereby incorporated by reference.

TECHNICAL FIELD

[0002] This disclosure relates generally to the aging of alcoholic beverages such as distilled spirits, beer, and wine, and more specifically to the rapid aging of alcoholic beverages using controlled mechanically induced cavitation to enhance maturity and drinkability of resulting beverages thereby simulating traditional aging.

BACKGROUND

[0003] The most desired of spirits are aged. Examples include whisky, scotch, bourbon, tequila, and many others. Likewise, beer and wine also are aged prior to drinking. These aged products are more expensive by virtue of the time and resources expended during the aging process and arguably have more enjoyable flavors and aromas than alcoholic beverages that are non-aged. The aging process softens the 'burn' of the ethanol while smoothing out flavors and adding even more pleasant ones. Further, undesirable and even poisonous alcohols and other products are largely converted to more desirable and less offensive tasting esters during aging.

[0004] Traditionally, newly distilled spirits are aged in a variety of ways, with perhaps the most common being barrel aging. Newly distilled or "white" whisky, for example, is commonly aged in Southern white oak barrels that have been burnt or charred on the inside. Aging exposes the alcohol and other compounds both to oxygen in the air and the storage materials themselves (charred oak for instance) for long periods of time, usually many years or even decades. This alters the chemical structure of many of the alcoholic compounds and changes the color, aroma, and flavor of the resulting liquor in various and mostly beneficial ways. Beer and wine also are aged in aging vessels for similar reasons.

[0005] Alcoholic beverages are created through fermentation of a biological product, be it grapes, grain mash, fruit, plants, or another product. In the case of distilled spirits, distillation yields primarily ethanol, but also produces aldehydes, esters, and fatty acids, all of which have very specific flavors and aromas. It is at least in part the unique combination of these chemicals that make spirits different from one another. Multiple distillations and filtering can remove many of these compounds to create a "clean" or aromaless and flavorless spirit such as Vodka. The choice of raw materials, the fermentation process, and the distillation technique and equipment will all contribute to the overall chemical composition and therefore the aroma and taste of the final product.

[0006] Distilling alcohol creates beneficial byproducts, as mentioned above, but also creates bad-tasting and poisonous byproducts, including butane, methanol, hydrazines, acetates, and acetaldehydes. Both good and bad byproducts often are grouped together under the label "congeners." Fortunately, the good congeners happen to be quite stable, whereas the bad ones break down or are converted to more desirable compounds or at least to inert compounds over time. Aging a distilled product allows this time to pass, thereby decreasing the amount of bad tastes and poisons and increasing the amount of good flavor and aroma. Research has shown that basically all the effects of aging occur within fifteen years with virtually no perceptible change in aroma and flavor occurring thereafter. This is part of the reason why, for instance, most scotch is aged for between 12 and 15 years.

[0007] There have been attempts over the years to obtain the beneficial chemical changes in distilled spirits caused by aging without having to wait for years for them to occur. Some distillers, for example, prefer to age spirits in small barrels, which increases the relative area of contact between the spirits and the inside of the barrel. This has not been completely successful however and still can require several years to obtain desired benefits. More recently. so-called artificially accelerated aging has become known and has been tried. In one such process, a distilled spirit is pumped through an oxygenated chamber, where it is subjected to high-intensity ultrasonic energy or sound waves. The agitation caused by the sound waves induces esterification. It has been shown that this process can at least to some extent artificially replicate the aging process of liquor such as whisky by inducing more harsh "higher" alcohols like isopropanol to react with fatty acids to produce esters with more pleasant flavors. This is often referred to "oxidation" in the industry. While it is claimed that ultrasound aging can reduce the production of aged liquors from years to hours, the result has not been completely satisfactory at least in part because it has proven very challenging to scale up ultrasound processes to commercial production volumes.

[0008] A need exists for a method and apparatus that can obtain the same beneficial chemical reactions and infusion of flavors in alcoholic beverages such as distilled spirits, beer and wine caused by traditional aging, but obtains them in hours rather than years. The method should be able to age alcoholic beverages in a continuous process and in commercial volumes. It is to the provision of such a method and an apparatus for carrying out the method that the present invention is primarily directed.

SUMMARY

[0009] Briefly described, a method and apparatus is disclosed, for aging an alcoholic beverage such as distilled spirits, beer, or wine (which may collectively be referred to herein as "spirits") in hours rather than years. The process can be used to age spirits in commercial volumes and in such a way that the final product is virtually indistinguishable from spirits aged for years in barrels or other aging vessels. The method includes passing liquid spirits through a treatment zone and inducing is the liquid highly energetic cavitation events. Preferably, the liquid is passed through a controlled cavitation reactor such as that disclosed in U.S. Pat. Nos. 8,465,642; 8,430,968; 7,507,014; 7,360,755; and 6,627,784, each of which is hereby incorporated by reference in its entirety. The reactor has a closed cylindrical housing within which a cylindrical rotor is rotatably mounted. The treatment zone is defined between the outer surface of the rotor and the inner surface of the housing.

Bores are formed through the outer surface of the rotor and when the rotor is rotated at a high rate with spirits in the treatment zone, very energetic cavitation events are generated within the bores.

[0010] The cavitation events within the bores in turn generate micro shock waves that propagate through the spirits in the treatment zone. The shock waves, which are very highly energetic, break down undesirable alcohols, tannins, and other chemicals in the spirits just as traditional aging does, thus mellowing the taste of the spirits. In one exemplary embodiment, charred wood chips are mixed with distilled spirits and the cavitation events draw out the flavors from the wood chips and infuse them in the distilled spirits. The result is liquor comparable in color, aroma, and taste to that obtained from years of aging in a barrel, but requiring minutes or hours rather than years to obtain. In another embodiment, hops are added to beer and the shock waves draw out the flavor of the hops and infuse the flavor in the beer more efficiently than traditional aging.

[0011] With the proliferation of craft breweries and their more heavily hopped beers, the demand for hops and their prices have increased. Typically only about one third of the flavor potential is extracted from hops during traditional beer aging. Hops can be added for bittering purposes prior to fermentation or for flavor purposes post fermentation, often called dry hopping. Using the pressure fluctuations of shock waves from cavitation, hop flavor can be extracted and infused into beer much more efficiently in a very short time, This is accomplished in a relatively low shear environment to minimize protein damage to the hops and to minimize fines production. The ultimate result is a reduction in hops usage to produce a desired hops flavor in beer as well as higher yields due to more efficient flavor extraction and less beer soaked hop waste. Other flavorings such as coffee or chocolate also can be added,

[0012] Red "young wines" often have a strong tannin taste. Reduction of tannins commonly requires aging of wine in barrels or stainless steel aging vessels for many years. This reduces the tannins and leads to improved taste and thus increased value, This tannin reduction is a chemical reaction and it has been found that this chemical reaction can be sped up greatly by passing young wine through a controlled cavitation reactor according to the present invention. Accordingly, the present invention can be applied to wine, with or without added flavorings, to reduce or eliminate the traditional aging process.

[0013] These and other aspects, features, and advantages of the present invention will be better appreciated upon review of the detailed description set forth below taken in conjunction with the accompanying drawing figures, which are briefly described as follows,

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is a schematic view showing one embodiment of an apparatus for carrying out the method of the present invention.

[0015] FIG. **2** is a schematic view showing another embodiment of the invention used here in conjunction with traditional pre-aging.

[0016] FIG. **3** is a schematic view showing yet another embodiment of the invention used here in conjunction with traditional post-aging.

DETAILED DESCRIPTION

[0017] The invention will now be described in more detail and this description should be reviewed in conjunction with the accompanying drawing figures for enhanced clarity. Mechanically induced and controlled cavitation such as that produced by the controlled cavitation devices disclosed in the incorporated references is used according to the present invention to obtain artificial aging of alcoholic beverages such as distilled spirits on a high volume commercial scale. In one embodiment, the system includes a reservoir tank for holding an alcoholic beverage during the aging process. A pump circulates the beverage from the reservoir tank, through the controlled cavitation device, and back to the reservoir tank. In this way, the alcoholic beverage being aged can be circulated through the controlled cavitation device for as many cycles as necessary to obtain the desired degree of aging and flavoring.

[0018] In another embodiment, charred wood chips are added to distilled spirits and become entrained in the flow through the controlled cavitation device. The intense cavitation to which the spirits and wood chips are subjected in the cavitation device penetrate the wood chips and extracts color and flavor from them, which is infused into the liquid. This process also drives the liquid spirits into and out of the pores of the chips, which helps filter some undesirable compounds from the mix in much the same way that the charred interior of an oak barrel does over years of traditional aging. In other embodiments, hops and/or other flavors may be added to the alcoholic beverage for the aging of beers for example. Other flavoring and/or aroma sources such as fruits, oils, chocolates, flowers, spices, and other substances may be added for the production of a variety of products from flavored liquors to beer to wine and even to perfumes.

[0019] When used to age distilled spirits, the system of this invention can run for varying periods of time to obtain numerous cycles of a mixture through the controlled cavitation device. Varying amounts of char and various species of wood chips and/or flavoring may be selected to obtain a desired flavor, color, and filtration effect. It has been found that the time required for aging can range from a few minutes to many hours depending upon the composition of the original distilled spirit, the amount of desired color and flavor desired, and the number of years of traditional aging being matched. A heat exchanger may also be incorporated in the loop for longer runs to dissipate heat build up caused by the cavitation device and any exothermic reactions occurring in the mix.

[0020] Internal clearances within the controlled cavitation device such as the space between the rotor and interior wails of the housing may be adjusted to accommodate different size charred wood chips. This is advantageous since wood chip surface area is an independent variable in the resultant aging process. Wood chips may also be substituted with a replaceable wooden ring insert that is internally concentric to the controlled cavitation device housing. Such a ring can be charred prior to an aging process to obtain the same desirable characteristics as the charred interior walls of a traditional oak barrel. In either event, the spirits are forced into and out of the pores of the charred wood chips or charred ring by the high intensity shock wave induced pressure variations, thereby releasing color and flavor into the mix. The intense pressure fluctuation also functions to remove sulfur species and other contaminants from distilled

spirits through a filtration process akin to charcoal filtration. More specifically, the spirits are forced by the pressure variations into and out, of the pores and particles of the charred wood, which filters the spirits in much the same way as an activated charcoal filter bed. Advantageously, the flavoring, coloring, and filtering process are accelerated by orders of magnitude over traditional barrel aging processes.

[0021] As mentioned above, ultrasound has been used in the past to obtain somewhat accelerated aging of spirits. The system of the present invention has many advantages over ultrasound treatment. For instance, ultrasound aging systems can work acceptably well on a small or laboratory scale, but such systems are difficult to scale up and replicate laboratory results in commercial volumes. The use of controlled cavitation in the present invention provides similar or near identical results at nearly any commercial volume. Cavitation events in the controlled cavitation device typically produce intense shock waves in a liquid being treated that expose the molecules in the liquid to far higher energies than are possible with ultrasound, This can result in more rapid flavor intensification and more rapid conversion of undesirable alcohols in the mixture into esters and other less objectionable compounds.

[0022] Gasses such as oxygen also may be added to the mix to accelerate the oxidation and conversion of undesirable alcohols and other chemicals. Also ultrasound liquor aging devices rely on small clearances and mechanical shear to enhance the effects of the ultrasound aging process. These requirements are not conducive to particulates like wood chips being added to the liquor mix. A controlled cavitation device of the present invention can easily accommodate wood chips and other solids because of its inherent low shear and relatively large internal clearances.

[0023] The same principles used to extract flavor and color from charred wood chips in liquor aging can be used to extract sugars, starches, oils, and other substances from woods and other lignocellulosic material in applications such as ethanol and biogas production. Substances such as waste food or algae can experience component extraction in a similar way. In such processes, the intense pressure fluctuations caused by the cavitation induced shock waves force a solvent into a solid to remove entrapped components such as sugars and starches. These intense high energy shock waves are also capable of causing lysis of pressurized bodies like cells. Examples of this include treatment of algae or bacteria with the cavitation induced lysis allowing for oil and carbohydrate extraction or pasteurization. Cavitation can also reverse hornification where the pore structure of a lignocellulosic material dries and bonds to itself limiting future use of its natural capillary system. The pressure fluctuations can force solvent into this structure and reopen it to near its original condition prior to drying.

[0024] FIG. **1** illustrates in simplified schematic form a controlled cavitation reactor suitable for use in carrying out the methodology of the present invention. Such a reactor is described in detail in the incorporated references, and so will be describe only generally here. The reactor **11** comprises a reservoir tank **12** for holding a liquid alcoholic beverage during the aging process. Liquid is drawn from the reservoir tank **12** through conduit **13** by a pump **14** and delivered through a flow meter **16** and conduit **17** to a controlled cavitation reactor **18**. The controlled cavitation reactor **18** generally comprises a cylindrical housing having an internally mounted cylindrical rotor. A space is defined between the outer peripheral surface of the rotor and the inner peripheral surface of the housing and this space is referred to as the cavitation zone. Cavitation-inducing structures such as radial bores are formed in or one the outer peripheral surface of the rotor. The rotor is rotated within the housing by an electric motor **19**.

[0025] The liquid is pumped through the cavitation reactor within which it flows through the cavitation zone. As the rotor is rotated at a high rate, continuous cavitation events are induced in the liquid within the radial bores. This, in turn, produces highly energetic shock waves caused by continuously collapsing cavitation bubbles to propagate through the liquid in the cavitation zone. These shock waves induce the reactions described above within the alcoholic beverage, thereby duplicating traditional aging processes, but doing so in minutes rather than years. Charred wood chips may be mixed with the liquid, particularly when aging distilled spirits, to infuse the white spirits with color and flavor similar to that, resulting from years of aging in charred barrels. After treatment in the reactor **18**, the liquid flows through conduit **21** and may flow through a heat exchanger **22** to remove unwanted heat induced by the energy of cavitation. The cooled liquid then flows through conduit **23** and inlet **26** back to the reservoir tank **12**. The liquid and entrained chips and/or other flavorings if desired may be circulated through the cavitation reactor as many times as desired to obtain, a desired level of aging, flavor, and aroma. Then, it can be extracted as an aged and flavored alcoholic beverage, as indicated by arrow **28**.

[0026] FIGS. **2** and **3** illustrate hybrid systems for aging distilled spirits that include artificial aging with high energy cavitation in conjunction with traditional aging. Of course, such a hybrid system can be used in the aging of beer and wine in the same way. In FIG. **2**, distilled spirits are partially aged in a traditional manner such as being left in a charred oak barrel **27** for a specified period of time. This time preferably is far less than the years required for full barrel aging and results in partial aging, partial filtration and partial infusion of the desired flavors of the charred oak into the distilled spirits, The partially aged spirits can then be subjected to the cavitation induced aging in the apparatus described above for one or more cycles. Charred wood chips and/or other flavorings can be introduced if desired to obtain additional flavoring, coloring, and filtration during the process. The result is a fully aged liquor having characteristics unique to the charred oak barrel in which it was partially aged, but also having the full robust aging that traditionally only results from years of residence in oak barrels. Again, the total time to obtain the fully aged liquor product is a fraction of the time required to obtain the same benefits with traditional aging.

[0027] FIG. **3** illustrates an, alternate hybrid process for obtaining similar results. Here, freshly distilled spirits are delivered from the distiller directly to a controlled cavitation device **11** according to the invention. As described above, the spirits are circulated through the controlled cavitation reactor or cavitator for a predetermined number of cycles, with or without the addition of charred wood chips and other flavoring and filtering media. After treatment for minutes or hours in the cavitation reactor, the distilled spirits are partially aged as if they had resided in traditional charred oak barrels for months or even years. The partially aged spirits may then be delivered to traditional charred oak barrels or other aging vessels for further aging in a more

traditional manner. This may be desired, for instance, to infuse the resulting liquor with unique flavors from the barrel or for other reasons, After traditional aging in the barrel for a time far less than the several years usually required, the liquor is fully aged and virtually indistinguishable from its more venerable predecessors. Again, the total time to obtain the desirable flavor and character of liquor aged for years is reduced to a fraction of that time using a combination of the methodology of the present invention and traditional aging techniques.

[0028] The invention has been described herein in terms and within the context of exemplary embodiments and methodologies considered by the inventors to represent the best modes of carrying out the invention. However, the illustrated embodiments are not intended to and should not be construed to limit the scope of the invention. For example, while aging distilled spirits has been used in some instances as an example of the use of this invention, the invention itself is much broader than this. For instance, the methodology of the invention has been found useful in beer manufacturing, where pumping beer through a controlled cavitation reactor with hops and other flavorings can simulate the aging process in a fraction of the time. Wine can also be aged using the methodology of this invention. When aging wine, the wine may be pumped through a controlled cavitation reactor with wood chips and/or other flavorings. Exposure to shock waves in the cavitation zone accelerates many of the chemical reactions that naturally occur slowly with traditional beer and wine aging. Thus, the term "spirits" as used herein is meant to be construed to encompass beer and wine as well as distilled spirits. Any desired flavoring can be included in a stream of spirits, beer, or wine being aged including those mentioned and, for instance, coffee and chocolate (sometimes used to flavor beer) an any other flavoring desired. It will be appreciated by the skilled artisan, therefore, that a wide gamut of additions, deletions, and modifications, both subtle and gross, may be made to the example embodiments without departing from the spirit and scope of the invention exemplified by such embodiments.

What is claimed is:

1. A method of aging an alcoholic beverage to produce an aged beverage, the method comprising the steps of:

(a) obtaining a volume of alcoholic beverage to be aged; and

(b) subjecting the alcoholic beverage, to cavitation within a cavitation zone of a controlled cavitation reactor.

2. The method of claim **1** wherein step (b) comprises circulating the alcoholic beverage through the cavitation zone two or more times.

3. The method of claim **1** further comprising the step of introducing additives to the alcoholic beverage prior to step (b).

4. The method of claim **3** wherein the additives comprise wood chips.

5. The method of claim **4** further comprising charring the wood chips prior to introducing them to the distilled spirits.

6. The method of claim **3** wherein the additives comprise flavorings.

7. The method of claim **1** further comprising the step of at least partially aging the alcoholic beverage in a vessel prior to step (b).

8. The method of claim **7** wherein the vessel comprises a charred barrel.

9. The method of claim **1** further comprising the step of at least partially aging the alcoholic beverage in a vessel following step (b).

10. The method of claim **9** wherein the vessel comprises a charred barrel.

11. The method of claim **1** further comprising the step following step (b) of cooling the alcoholic beverage in a heat exchanger.

12. The method of claim **1** wherein the alcoholic beverage comprises distilled spirits.

13. The method of claim **1** wherein the alcoholic beverage comprises beer.

14. The method of claim **13** further comprising adding hops to the beer prior to step (b).

15. The method of claim **1** wherein the alcoholic beverage comprises wine.

16. A method of aging an alcoholic beverage to produce an aged alcoholic beverage, the method comprising the steps of:

(a) collecting the alcoholic beverage in a reservoir tank;

(b) pumping the alcoholic beverage from the reservoir tank to a controlled cavitation reactor having a cavitation zone;

(c) passing the alcoholic beverage through the cavitation zone of the controlled cavitation reactor to break down undesirable components in the alcoholic beverage normally broken down by time in an aging vessel to produce an aged alcoholic beverage;

(d) moving the aged alcoholic beverage back to the reservoir tank; and

(e) optionally repeating steps (b) through (d) to expose the aged alcoholic beverage to cavitation within the cavitation zone a predetermined number of times to age the alcoholic beverage further; and

(f) collecting the aged alcoholic beverage.

17. The method of claim **16** further comprising the step of introducing additives into the alcoholic beverage prior to step (c).

18. The method of claim **17** wherein the additives comprise wood chips.

19. The method of claim **18** further comprising the step of charring the wood chips prior to introducing them into the alcoholic beverage.

20. The method of claim **16** further comprising the step prior to step (a) of partially aging the alcoholic beverage in an aging vessel.

21. The method of claim **20** wherein the aging vessel comprises a charred wood barrel.

22. The method of claim **12** further comprising the step following step (f) of storing the collected aged alcoholic beverage in an aging vessel for a predetermined period of time.

23. The method of claim **22** wherein the aging vessel comprises a charred wooden barrel.

24. The method of claim **16** wherein the alcoholic beverage comprises a distilled spirit, beer, or wine.

* * * * *