

METHODS FOR DETERMINING PARTICLE CONCENTRATION IN A FLUID AND SYSTEMS THEREFOR

PRIORITY CLAIM

[0001] The present application claims priority to Singapore Patent Application No. 10201400476S, filed 7 March, 2014.

FIELD OF THE INVENTION

[0002] The present invention generally relates to methods for determining particle concentration in a fluid and systems therefor, and more particularly relates to methods for determining fat and solid-non-fat concentration in milk and systems therefor.

BACKGROUND

[0003] Milk is one of the top food products most vulnerable to adulteration. In most typical cases of adulteration, fresh milk is deliberately diluted with a large amount of water—the tactic of which is known as “watering-down”. The main motivation driving unscrupulous enterprises to commit such frauds is the huge economic benefits which can be potentially derived from the sale of these tampered foods. More importantly, it is also the difficulty in efficiently detecting food frauds which further encourages such unethical practices to proliferate in an increasingly complex food supply chain.

[0004] The classical techniques for milk measurement are performed using chemical analytical approaches. In these methods, chemical solvents such as sulfuric acid are added to milk samples so as to single out the fat by dissolving all the other milk components such as protein in particular. The separated fat floating on the sample’s surface may then be measured by a calibrated butyrometer. Although the chemical analytical approaches can produce accurate measurements on the fat

content, the processes are time-consuming and usually require skilled expertise to carry out the test protocol. The chemical methods are, therefore, unsuitable for large volume inspection within a very short time-frame due to the limited expiry life of fresh milk.

[0005] Rapid test techniques for milk measurements have since been developed to substitute the prior chemical analytical methods. One of which is based on an acoustic approach whereby milk compositions are typically measured from the ultrasonic reflection of the particles suspended in the milk sample. While the acoustic technique offers a faster means as compared to the classical methods, it is considered to be less accurate and is highly susceptible to errors induced by the floating particles on the surface (such as fat films in particular) as well as the temperature of the milk samples. As a result, the current ultrasonic milk analyzers are often encumbered with a thorough rinsing and cleaning process after every testing to the effect of slowing down the testing operation.

[0006] Alternatively, electro-optical techniques have been deployed as rapid means of measuring milk compositions within a time frame of seconds. In many of these prior arts, the measurements are based on the infra-red (IR) or near-infra-red (NIR) absorbance of the samples at the absorption wavelengths corresponding to the functional groups of fat, protein and lactose molecules. Due to the high sensitivity of IR and NIR absorbance technique, however, the measurements can exhibit much variation attributed to the slight molecular difference in the components of natural milks. This can result in poor consistency of the measurements on milk samples with the same concentrations in the main ingredients but belonging to different breeds of dairy-cattle.

[0007] There are some electro-optical techniques which make use of light penetration depth or permeability in the milk samples as a basis for fat measurement. Milk characterization using such techniques alone, however, may not be accurate as light permeability can also be influenced by many other particles such as protein or lactose in the milk sample which can potentially absorb or reflect the incident light. There are other techniques which use light refraction in the sample to characterize milk compositions but these usually require extremely fine calibration on the refractometric setup which is difficult to implement in a practical analyzer.

[0008] Thus, what is needed is a rapid yet accurate method to measure the fat concentration of the milk. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY

[0009] A method for determining a particle concentration in a fluid is provided in accordance with some examples of the present embodiment. The includes diluting the fluid in an optically transparent sample holder, projecting a light beam on a first side of the sample holder and detecting the light beam scattered by particles at a position facing a second side of the sample holder, the first side of the sample holder forming an angle with the second side of the sample holder. The method further includes determining the particle concentration in the fluid from an intensity of the scattered light beam.

[0010] In accordance with some examples of the present embodiment, a method for determining a first particle concentration and a second particle

concentration in a fluid is provided. The method includes diluting the fluid in an optically transparent sample

holder, projecting a light beam on a first side of the sample holder and detecting the light beam scattered by the first particles at a position facing a second side of the sample holder, the first side of the sample holder forming an angle with the second side of the sample holder. The method further includes determining the first particle concentration in the fluid from an intensity of the scattered light beam, a weight of the first particles being determined from the first particle concentration, weighing the sample holder containing the fluid to obtain a total weight thereof, determining a weight of the second particles from the total weight of the sample holder and the weight of the first particles, and determining the second particle concentration from the weight thereof.

[0011] In accordance with some examples of the present embodiment, a system for determining particle concentration in a fluid is provided. The system includes an optically transparent sample holder, a light beam source and a detector. The optically transparent sample holder is configured to hold a diluted fluid containing particles. The light beam source is configured to project a light beam on a first side of the sample holder. And the detector is configured to detect the light beam scattered by the particles at a position facing a second side of the sample holder, the first side of the sample holder forming an angle with the second side of the sample holder and an intensity of the scattered light beam being used to determine the particle concentration in the fluid.

[0012] And in accordance with some examples of the present embodiment, a system for determining a first particle concentration and a second particle concentration in a fluid is provided. The system includes an optically transparent sample holder, a light beam source, a detector and a weighing scale. The

optically transparent sample holder is configured to hold a diluted fluid containing
first

particles and second particles. The light beam source is configured to project a light beam on a first side of the sample holder. The detector is configured to detect the light beam scattered by the first particles at a position facing a second side of the sample holder, the first side of the sample holder forming an angle with the second side of the sample holder. An intensity of the light beam is used to determine the first particle concentration in the fluid and a weight of the first particles is determined from the first particle concentration. The weighing scale is configured to weigh the sample holder with the diluted fluid, the total weight of the sample holder and the diluted fluid being used to determine a weight of the second particles to use for determining the second particle concentration.

[0012a] In view of the above, in accordance with an aspect of the present embodiment, there is provided a method for determining particle concentration of first particles in a fluid, wherein the fluid further comprises at least second particles, wherein the first particles have a first particle size bigger than a second particle size of the second particles. The method comprises diluting the fluid in an optically transparent sample holder without dissolving the second particles; projecting a light beam on a first side of the sample holder; detecting the light beam scattered by the first particles at a position facing a second side of the sample holder; and determining the particle concentration of the first particles in the fluid from an intensity of the scattered light beam, wherein the first side of the sample holder forms an angle with the second side of the sample holder is 90°.

[0012b] In accordance with another aspect of the present embodiment, there is provided a method for determining a first particle concentration and a second particle concentration in a fluid. The method comprises diluting the fluid in an optically transparent sample holder to a degree of dilution of at least one hundred parts of

diluent to one part of the fluid; projecting a light beam on a first side of the sample holder; detecting the light beam scattered by the first particles at a position facing a second side of the sample holder; determining the first particle concentration in the fluid from an intensity of the scattered light beam, a weight of the first particles being determined from the first particle concentration; weighing the sample holder containing the fluid to obtain a total weight thereof; determining a weight of the second particles from the total weight of the sample holder and the weight of the first particles; and determining the second particle concentration from the weight thereof, wherein the first side of the sample holder forms an angle with the second side of the sample holder.

[0012c] In accordance with another aspect of the present embodiment, there is provided a system for determining particle concentration of first particles in a fluid, wherein the fluid further comprises at least second particles, wherein the first particles have a first particle size bigger than a second particle size of the second particles. The system comprises: an optically transparent sample holder configured to hold a diluted fluid containing the first particles and the second particles; a light beam source configured to project a light beam on a first side of the sample holder; and a detector configured to detect the light beam scattered by the first particles at a position facing a second side of the sample holder, an intensity of the scattered light beam being used to determine the particle concentration of the first particles in the fluid, wherein the first side of the sample holder forms an angle with the second side of the sample holder is 90°.

[0012d] In accordance with yet another aspect of the present embodiment, there is provided a system for determining a first particle concentration and a second particle concentration in a fluid. The system comprises: an optically transparent sample holder

configured to hold a diluted fluid containing first particles and second particles; a light beam source configured to project a light beam on a first side of the sample holder; a detector configured to detect the light beam scattered by the first particles at a position facing a second side of the sample holder, an intensity of the light beam being used to determine the first particle concentration in the fluid, a weight of the first particles being determined from the first particle concentration; a weighing scale configured to weigh the sample holder with the diluted fluid; and a microcontroller unit configured to receive the total weight of the sample holder and the diluted fluid from the weighing scale to determine a weight of the second particles and determine the second particle concentration using the weight of the second particles, wherein the first side of the sample holder forms an angle with the second side of the sample holder.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views and which together with the detailed description below are incorporated in and form part of the specification, serve to illustrate various embodiments and to explain various principles and advantages in accordance with a present embodiment.

[0014] FIG. 1, comprising FIGs. 1A, 1B and 1C, depicts a system for determining particle concentration in a fluid in accordance with a present embodiment, wherein FIG. 1A depicts a top view of the system for determining particle concentration in a fluid, FIG. 1B depicts a side view of the system for determining particle concentration in a fluid, and FIG. 1C depicts a schematic diagram of a range of the angle covered by the perpendicular scattered light beam in the system of FIGs. 1A and 1B in accordance with the present embodiment.

[0015] FIG. 2, comprising FIGs. 2A and 2B, depicts a system for determining particle concentration in a fluid in accordance with another embodiment, wherein FIG. 2A depicts a top view of the system for determining particle concentration in a fluid in accordance with the other embodiment and FIG. 2B depicts a side view of the system for determining particle concentration in a fluid in accordance with the other embodiment.

[0016] FIG.3 depicts a schematic diagram of a system for determining particle concentration in a fluid in accordance with the present embodiment.

[0017] FIG.4 depicts a flowchart of a method for determining a particle concentration in a fluid in accordance with the present embodiment.

[0018] FIG. 5 depicts a flowchart of a method for determining a particle concentration in a fluid in accordance with the present embodiment.

[0019] FIG. 6 depicts a flowchart of a method for determining a particle concentration in a fluid in accordance with the present embodiment.

[0020] Table 1 shows fat concentrations of milk samples diluted to varying degree for the experiment in accordance with the present embodiment.

[0021] FIG.7 depicts a graph of an intensity of the scattered light beam versus milk fat concentration in accordance with the present embodiment.

[0022] Table 2 shows computed fat concentrations based on the fitted equation in accordance with the present embodiment.

[0023] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the block diagrams or flowcharts may be exaggerated in respect to other elements to help to improve understanding of the present embodiments.

DETAILED DESCRIPTION

[0024] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background of the invention or the following detailed description. It is the intent of the present embodiment to present novel methods for determining particle concentration in a fluid and systems therefor, and more particularly to present methods for determining fat and solid-non-fat concentration in milk and systems therefor. The present methods and systems provide a fast and accurate way for determining fat particle concentration in milk. Additionally, the present methods and systems provide a fast and accurate way for determining solid-non-fat concentration in milk where the solid-non-fat (SNF) has a smaller particle size than fats. Therefore, the present methods and systems provide a fast and accurate way to obtain two measurements which in turn improves efficiency and accuracy. Furthermore, the present methods and systems provide a more desirable and environment-friendly manner wherein no reagents or solvents are applied in the fluid.

[0025] The present methods and systems will be described with reference to milk; however, it can be understood that the present methods and systems are applicable to provide measurements for other emulsions or suspension fluids containing at least one type of particle sufficiently large to induce light scattering effects. These fluids may include edible oil, fruit juice, syrups, milk powder solution or even blood suspension.

[0026] The systems and methods provided herein seek to allow rapid measurement of the basic nutritious content of fresh milk. Basically, the nutrients in fresh milk can be classified into two groups, namely fat and SNF where SNF comprises mainly of

protein, lactose and calcium. Any act of adulteration either by dilution with water or addition of cheaper substitutes can be reflected by the change in the absolute concentration of fat or SNF. Embodiments of the invention provide accurate measurement of fat within a few simple procedures using optical techniques, so that the quality of fresh milk in supply volumes can be effectively controlled and fraud cases can be detected with a low false negative error. Additionally, the concentration of the SNF can be further determined via a weight elimination technique which involves subtracting the known weight of the fat (derived from the fat concentration measurement based on the optical technique) from the total weight of the milk sample.

[0027] Rapid, user-friendly and reagent-free technology is provided for determining the concentration of fat in a fresh milk sample. In an example implementation, perpendicular light scattering effect of the fat particles in an extremely diluted milk sample is used to derive the original fat concentration. The incident light is preferably in the form of laser or collimated beam. The milk is preferably homogenized first before subjecting to the test protocol. Importantly, the present methods do not involve the use of organic solvent or chemical reagent intended for the purpose of dissolving the protein particles.

[0028] A system for determining particle concentration in a fluid is provided in accordance with a present embodiment. The system comprises an optically transparent sample holder configured to hold a diluted fluid containing particles; a light beam source configured to project a light beam on a first said of the sample holder; and a detector configured to detect the light beam scattered by the particles at a position facing a second side of the sample holder, an intensity of the scattered light beam being used to determine the particle concentration in the fluid, wherein the first side of the sample holder forms an angle with the second side of the sample holder.

[0029] In an embodiment, the angle formed by the first side and the second side of the sample holder is approximately 90°.

[0030] In an embodiment, the system further comprises a casing configured to shield the system from interference from other light beams.

[0031] In an embodiment, the detector is a photodiode.

[0032] In an embodiment, the system further comprises a dispenser configured to dispense a predetermined amount of the fluid into the sample holder and/or dispense a predetermined amount of a dilute into the sample holder.

[0033] In an embodiment, the system further comprises a microcontroller unit to control on-off of the light beam source and the detector, and/or to control the dispenser.

[0034] In an embodiment, the system further comprises a display configured to display the particle concentration.

[0035] In an embodiment, the fluid is milk and the particles are fat particles.

[0036] A system for determining a first particle concentration and a second particle concentration in a fluid is provided. The system comprises a optically transparent sample holder configured to hold a diluted fluid containing a first particle and a second particle; a light beam source configured to project a light beam on a first said of the sample holder; a detector configured to detect the light beam scattered by the first particles at a position facing a second side of the sample holder, an intensity of the light beam being used to determine the first particle concentration in the fluid, a weight of the first particle being determined from the first particle concentration; and a weighing scale configured to weigh the sample holder with the diluted fluid; the total weight of the sample holder and the diluted fluid being used to determine a

weight of the second particles which is used to determine the second particle concentration, wherein the first side of the sample holder forms an angle with the second side of the sample holder.

[0037] In an embodiment, the first particles have a first particle size bigger than a second particle size of the second particles.

[0038] In an embodiment, the fluid is milk, the first particles are fat particles and the second particles are solid-non-fat particles.

[0039] Now referring to FIG.1, a system 100 for determining a particle concentration in a fluid is depicted in accordance with a present embodiment. FIG. 1A shows a top view of the system 100 while FIG. 1B shows a side view of the system 100. The system 100 comprises a sample holder 112 for holding a milk sample pre-diluted with water. The sample holder 112 is optically transparent, for example, in the form of a glass bottle, curvette or any other containers unlimited by size or shape as long as the light beam can be transmitted through. The system 100 further comprises a light source 114 for projecting a light beam on a first side of the sample holder 112 and a detector 116 for detecting the light beam scattered by the particle at a position facing a second side of the sample holder 112. The first side of the sample holder 112 forms an angle with the second side of the sample holder 112. It is understood that the detector 116 can detect the light beam scattered by the particle within an area around the direction facing the second side of the sample holder. The angle of scattering used in the present embodiment as shown in FIGs. 1A and 1B is perpendicular, but the present embodiment is also applicable to scattering angles approximately perpendicular to the path of the incident beam (see FIG. 1C).

[0040] The light beam may be a low-intensity laser beam, and preferably, a red laser (620 – 750 nm wavelength) as the spectrum is predominantly scattered by the fat particles in an extremely diluted milk sample. The detector 116 may be a photodiode which is capable of sensing and measuring the intensity of the light beam. The detector 116 is placed at a position facing another side of the sample holder in the direction perpendicular to the path of the laser beam, as shown in FIG 1. The intensity of the perpendicularly scattered light can be calibrated against the fat concentrations of various milk samples so as to establish a mathematical algorithm between the intensity of the perpendicularly scattered light and the fat concentrations. This calibrated algorithm can serve as the basis for computing the fat concentration in the actual deployment. An example of establishing the algorithm is described as follows.

[0041] The fat globules in homogenized milks typically assume an average diameter of 500 nm while that of protein is approximately 280nm. Since the fat globules are predominantly larger with sizes closer to the wavelength of red light (620 – 750nm), these account for much of the red light scattering in a milk sample. In a highly diluted sample, lactose and other inorganic salts are largely dissolved so that these contribute negligible light scattering. While milk protein may contribute to some light scattering, the effect is largely in the form of forward scattering over a wide area. Milk protein contributes little effects to perpendicular light scattering in a highly diluted sample, particularly in the red spectrum. The perpendicular scattering of light in a highly diluted milk sample may therefore be fully ascribed to the fat globules. In accordance with Beer Lambert's theorem, the equation relating the fat concentration and intensity of the perpendicular scattered light can be established as follows:

$$I_s = \frac{I_0}{m} (1 - e^{-k \cdot c \cdot d}) \quad \dots\dots (1)$$

where I_s and I_o is the intensity of the scattered and incident light respectively, m is known as the uniform scattered coefficient which can be taken as a constant in a highly diluted sample, μ_F is the scattering coefficient of the fat globules, x_F is the concentration of the fat globules and d is the distance over which light travelled in the milk sample.

[0042] In view of the small x_F value in a highly diluted sample, the equation can be further simplified into a linear relationship as follows:

[0043]
$$I_s = \frac{I_o}{m} \mu_F x_F d \quad \dots\dots (2)$$
 The intensity of the perpendicular scattered light can thus be calibrated against the fat concentrations of various milk samples in order to establish the measuring platform.

[0044] The light deployed in the technique may not be confined to red light but includes any other wavelengths in the visible, UV or infra-red spectra as long as scattering effects can be induced by the particles intended for detection. The light used may not be a laser beam but any other form of light, although collimated beams are preferred in the present embodiment.

[0045] The diluents used for diluting the milk sample may be water, and include any form of water such as deionized water, distilled water, tap water, chlorinated water, saline water or the like. The diluents may also include any other fluid comprises predominantly of water, inorganic fluid or fluids unintended for inducing chemical reaction on fat and protein in the milk sample.

[0046] While the intensity of the scattered light is used as a basis for fat measurement, it may be normalized with the intensity of the incident light or that of the transmitted light through the milk sample in executing the measurement. Therefore, light scattering metrics in the form of ratios such as Scattering-to-

Transmission Ratio (aka STR) or Scattering-to-Incident Ratio may be used in place of the absolute scattering intensity as described in the present embodiment.

[0047] Referring to FIG. 2, a system 200 for determining particle concentration in a fluid is depicted in accordance with another embodiment. FIG. 2A shows a top view of the system 200 while FIG. 2B shows a side view of the system 200. In comparison with the system 100, the system 200 further comprises a weighing scale 118 for weighing the sample holder containing the diluted milk sample. In accordance with the present embodiment, a weighing technique is provided to derive the SNF concentration of the milk sample. Based on the weight information and fat measurement obtained from the light scattering effects, the concentration of the SNF is derived by deducting the weight attributable to the fat particles and water from the total weight of the diluted milk sample, under the assumption that the SNFs take up negligible volume in the highly diluted sample. A fixed volume of the diluted milk sample may be weighed on a precision weighing

[0048] The concentration of SNFs can be resolved from the total weight of the diluted milk sample. The total weight of the sample is attributed to the combined weight of fat, SNFs and water as in the equation:

$$W_{TOTAL} = W_{FAT} + W_{WATER} + W_{SNF} \dots\dots (3)$$

where W_{TOTAL} , W_{FAT} , W_{WATER} and W_{SNF} refer to the weight of the sample, fat content, water content and SNF content respectively.

[0049] In a highly diluted milk sample, lactose and inorganic salts of the SNFs are largely dissolved so these constitute negligible volume of the sample. As the size of the protein is much smaller than those of fat, the volume of the protein is also assumed to be negligible. The water content in the milk sample can thus be computed by taking the difference between the sample's total volume and that of fat of which

the concentration is already known from the light scattering measurement. The equation in Eq. (3) can be translated into:

$$\begin{aligned} W_{\text{TOTAL}} &= W_{\text{FAT}} + D_{\text{WATER}} * V_{\text{WATER}} + W_{\text{SNF}} \\ &= W_{\text{FAT}} + D_{\text{WATER}} * (V_{\text{TOTAL}} - V_{\text{FAT}}) + W_{\text{SNF}} \\ &= W_{\text{FAT}} + D_{\text{WATER}} * (V_{\text{TOTAL}} - W_{\text{FAT}}/D_{\text{FAT}}) + W_{\text{SNF}} \dots\dots (4) \end{aligned}$$

where D_{WATER} is the density of water which can be taken to be 1g/ml, V_{TOTAL} is the total volume of the sample comprising the total weight, V_{FAT} is the volume of the fat globules and D_{FAT} is the density of fat. The density of milk fat may adopt the theoretical values, but it can also be obtained by curve-fitting with the experimental data.

[0050] The SNF content can thus be obtained:

$$W_{\text{SNF}} = W_{\text{TOTAL}} - W_{\text{FAT}} - D_{\text{WATER}} * (V_{\text{TOTAL}} - W_{\text{FAT}}/D_{\text{FAT}}) \dots\dots (5)$$

[0051] Referring to FIG 3, a system 300 comprises a light source 114, a detector 116 and a sample holder 112 containing the diluted milk sample. The light source 114 is pointed directly to one side of the sample holder 112 while the detector 116 is faced at another side of the sample holder in the direction perpendicular to the light path. The system 300 may further include a weighing scale 118 for SNF measurements. The sample holder 112 is placed on a precision weighing scale 118 for measuring the total weight of the diluted milk sample. The system 300 may further comprise a manual or automatic fluid dispenser 120 to dispense a fixed volume of milk in the sample holder, followed by a much larger amount of water. The dispenser 120 may be a standard glass pipette, micro-pipette, calibrated volumetric container, automatic pump, or any other manual or automatic dispenser unit capable of dispensing a fixed volume of fluid.

[0052] The system may also include an electronic circuit 122 to activate the light source and read the detector's output. The electronic circuit 122 may comprise a programmable device such as a microcontroller unit to control the operating sequence and execute specific tasks such as controlling the fluid dispenser 120, activating the light 114, reading the detector 116 output via analog-digital converter (ADC), receiving data from the weighing machine 118 via communication ports e.g., RS232, executing an embedded algorithm to analyze the input data to derive fat and SNF concentration results, and showing the results on an LCD unit 124. The whole system 300 may further be enclosed in a casing 126 to shield off any light which can potentially affect the photo-diode reading.

[0053] Referring to FIG. 4, a method for determining a particle concentration in a fluid is provided. The method comprises diluting the fluid in an optically transparent sample holder at step 410; projecting a light beam on a first side of the sample holder at step 420; detecting the light beam scattered by the particles at a position facing a second side of the sample holder at step 430; and determining the particle concentration in the fluid from an intensity of the scattered light beam at step 440, wherein the first side of the sample holder forms an angle with the second side of the sample holder.

[0054] In an embodiment, the angle formed by the first side and the second side of the sample holder is approximately 90°.

[0055] In an embodiment, diluting the fluid comprises diluting a predetermined amount of the fluid in a predetermined amount of a diluent.

[0056] In an embodiment, diluting the fluid comprises diluting one part of the fluid with at least 100 parts of the diluent.

[0057] In an embodiment, the diluting step comprises diluting the fluid without dissolving another type of particles with the presence of a solvent or a chemical reagent.

[0058] In an embodiment, the light beam is a red laser.

[0059] In an embodiment, the intensity of the scattered light beam has a linear relationship with the particle concentration.

[0060] In an embodiment, the fluid is milk and the particles are fat particles.

[0061] Referring to FIG. 5, a method for determining a first particle concentration and a second particle concentration in a fluid is provided. The method comprises diluting the fluid in an optically transparent sample holder at step 510; projecting a light beam on a first side of the sample holder at step 520; detecting the light beam scattered by the first particles at a position facing a second side of the sample holder at step 530; determining the first particle concentration in the fluid from an intensity of the scattered light beam at step 540, a weight of the first particles being determined from the first particle concentration; weighing the sample holder containing the fluid to obtain a total weight thereof at step 550; determining a weight of the second particles from the total weight of the sample holder and the weight of the first particles at step 560; and determining the second particle concentration from the weight thereof at step 570, wherein the first side of the sample holder forms an angle with the second side of the sample holder.

[0062] In an embodiment, the first particles have a first particle size bigger than a second particle size of the second particles.

[0063] In an embodiment, the fluid is milk, the first particles are fat particles and the second particles are solid-non-fat particles.

[0064] An example workflow of the fat and SNF measurement method in accordance with the present embodiment is shown in FIG 6. The measurement may begin at step 610 by placing a sample holder in the form of glass container or curvette onto a weighing scale to measure the baseline weight of the sample holder. At step 620, a fixed volume of milk may then be dispensed into the sample holder, followed by a fixed volume of water for the purpose of dilution. The dispensing of the milk sample and water may be done automatically with an electro-mechanical dispenser unit controlled by the micro-controller unit, or manually with a pipette or micro-pipette. It is also preferred that the degree of dilution is at least one hundred parts of water to one part of milk. At step 630, the red laser may then be activated by the electronic circuit, and at step 640, the output of the photodiode sensing the scattered light may be read by the microcontroller via analog-to-digital converter (ADC) or via an electrical measuring equipment such as an electrometer. At step 650, based on the acquired data, the microcontroller may perform a calibrated mathematical algorithm to compute the milk fat, or the computation can be performed manually based on the electrometer's readout. At step 660, the total weight of the diluted sample may be further measured by the weighing scale which may then be read manually or by the microcontroller via a communication port such as RS232. At step 670, with the known concentration of the fat, the weight of the fat in the sample can be derived and subtracted from the total weight of the sample for SNF concentration, in accordance to Eq.5. The computed results may finally be indicated on the display unit in the form of liquid crystal display (LCD) at step 680.

[0065] An experiment was performed for proof-of-concept for milk fat measurement according to embodiments of the invention. Milk samples of various fat

concentrations were prepared using commercially available fresh milk products with different degrees of dilution with water, as shown in Table 1.

[0066] The dilution was carried out by dispensing fresh milks of various volumes ranging from 50ul – 200ul in deionized water of volume of 20ml less the volume of milk dispensed. In this way, the volume of each diluted milk sample was consistently kept at 20ml. Low intensity red laser was projected onto a cuvette containing 4ml of the prepared samples. The photocurrent generated by the photo-diode capturing the scattered light was measured with an electrometer.

[0067] The graph 700 of the red light scattering captured on the photo-diode versus milk fat concentrations exhibits an almost linear relationship, is shown in FIG 7. A linear curve-fit on the plot generates the equation for calibrating the red light scattering against the fat milk fat concentration. The backward computational results on the milk fat concentrations by fitting the red light scattering data into the calibration equation are typically close to the expected fat concentrations, as illustrated in Table 2.

[0068] Thus, in accordance with the present embodiment, an advantageous, rapid and reliable method and system for determining milk fat and detecting adulteration by means of an optical technique are provided. The optical technique may be further complemented with precision weighing equipment so as to measure the concentration of other compositions, in particular that of solid-non-fat (SNF) particles based on the sample's weight information. The testing operation may be accomplished within a few seconds with good accuracy. The provided methods and systems also avoid using organic solvents and chemically reactive reagents which have been deployed in the prior arts. The provided methods and systems only make use of clean water to dilute the milk samples for facilitating the light scattering measurement. Embodiments of

the invention provide technical advantages as they allow milk testing to be performed rapidly and reliably on a simple and low-cost platform with minimum pollution.

[0069] The present embodiment aims to address the need for a rapid system and method for determining milk compositions and detecting adulteration in the huge global food supply chain. The present embodiment seeks to address the drawbacks of the prior arts associated with the complexity, speed and reliability of the test methods and systems. The present embodiment further seeks to achieve a cleaner approach of milk measurement without organic solvents or chemically reactive reagents other than water in the test protocol.

[0070] While exemplary embodiments have been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. For example, those skilled in the art will realize from the teachings herein that the present technology may also be applied to provide measurements for other emulsions or suspension fluids containing at least one type of particles sufficiently large to induce light scattering effects. These may include edible oil, fruit juice, syrups, milk powder solution or even blood suspension.

[0071] It should further be appreciated that the exemplary embodiments are only examples, and are not intended to limit the scope, applicability, operation, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention, it being understood that various changes may be made in the function and arrangement of elements and method of operation described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

CLAIMS

What is claimed is:

1. A method for determining particle concentration of first particles in a fluid, wherein the fluid further comprises at least second particles, wherein the first particles have a first particle size bigger than a second particle size of the second particles, the method comprising:
 - diluting the fluid in an optically transparent sample holder without dissolving the second particles;
 - projecting a light beam on a first side of the sample holder;
 - detecting the light beam scattered by the first particles at a position facing a second side of the sample holder; and
 - determining the particle concentration of the first particles in the fluid from an intensity of the scattered light beam,wherein the first side of the sample holder forms an angle with the second side of the sample holder is 90°.
2. The method in accordance with claim 1, wherein diluting the fluid comprises diluting a predetermined amount of the fluid in a predetermined amount of a diluent.
3. The method in accordance with claim 2, wherein diluting the fluid comprises diluting one part of the fluid with at least 100 parts of the diluent.

4. The method in accordance with claim 1, wherein the diluting step comprises diluting the fluid without dissolving the second particles with the presence of a solvent or a chemical reagent.

5. The method in accordance with claim 1, wherein the light beam is a red laser.

6. The method in accordance with claim 1, wherein the intensity of the scattered light beam has a linear relationship with the particle concentration.

7. The method in accordance with claim 1, wherein the fluid is milk, the first particles are fat particles, and the second particles are protein particles.

8. A method for determining a first particle concentration and a second particle concentration in a fluid, the method comprising:

diluting the fluid in an optically transparent sample holder to a degree of dilution of at least one hundred parts of diluent to one part of the fluid;

projecting a light beam on a first side of the sample holder;

detecting the light beam scattered by the first particles at a position facing a second side of the sample holder;

determining the first particle concentration in the fluid from an intensity of the scattered light beam, a weight of the first particles being determined from the first particle concentration;

weighing the sample holder containing the fluid to obtain a total weight thereof;
determining a weight of the second particles from the total weight of the sample holder and the weight of the first particles; and
determining the second particle concentration from the weight thereof,
wherein the first side of the sample holder forms an angle with the second side of the sample holder.

9. The method in accordance to claim 98, wherein the first particles have a first particle size bigger than a second particle size of the second particles.

10. The method in accordance to claim 98, wherein the fluid is milk, the first particles are fat particles and the second particles are solid-non-fat particles.

11. A system for determining particle concentration of first particles in a fluid, wherein the fluid further comprises at least second particles, wherein the first particles have a first particle size bigger than a second particle size of the second particles, the system comprising:

an optically transparent sample holder configured to hold a diluted fluid containing the first particles and the second particles;

a light beam source configured to project a light beam on a first side of the sample holder; and

a detector configured to detect the light beam scattered by the first particles at a position facing a second side of the sample holder, an intensity of the scattered light beam being used to determine the particle concentration of the first particles in the fluid,

wherein the first side of the sample holder forms an angle with the second side of the sample holder is 90°.

12. The system in accordance with claim 11, further comprising a casing configured to shield the system from interference from other light beams.

13. The system in accordance with claim 11, wherein the detector is a photodiode.

14. The system in accordance with claim 11, further comprising a dispenser configured to dispense a predetermined amount of the fluid into the sample holder and/or dispense a predetermined amount of a dilute into the sample holder.

15. The system in accordance with claim 14, further comprising:
a microcontroller unit to control on-off of the light beam source and the detector,
and/or to control the dispenser.

16. The system in accordance with claim 11, further comprising:
a display configured to display the particle concentration of the first particles.

17. The system in accordance with claim 11, wherein the fluid is milk, the first particles are fat particles and the second particles are protein particles.

18. A system for determining a first particle concentration and a second particle concentration in a fluid, the system comprising:

an optically transparent sample holder configured to hold a diluted fluid containing first particles and second particles;

a light beam source configured to project a light beam on a first side of the sample holder;

a detector configured to detect the light beam scattered by the first particles at a position facing a second side of the sample holder, an intensity of the light beam being used to determine the first particle concentration in the fluid, a weight of the first particles being determined from the first particle concentration;

a weighing scale configured to weigh the sample holder with the diluted fluid; and

a microcontroller unit configured to receive the total weight of the sample holder and the diluted fluid from the weighing scale to determine a weight of the second particles and determine the second particle concentration using the weight of the second particles,

wherein the first side of the sample holder forms an angle with the second side of the sample holder.

19. The system in accordance to claim 18, wherein the first particles have a first particle size bigger than a second particle size of the second particles.

20. The system in accordance to claim 18, wherein the fluid is milk, the first particles are fat particles and the second particles are solid-non-fat particles.