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Survey of Integrated Viscosity Sensing Methods for the Augmentation of Mobile Food Scanner and In-line Sensing

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ABSTRACT

Food and beverage production is a complex rheological field to work with because it involves dealing with a wide range of sample types and behaviors. Viscosity property of food has a significant impact on the food quality, and it could be a risk factor for evaluating the relationship between food retention and human health caries, hence urgently raises the need of immediate analysis and evaluation and monitoring the viscosity of food. Viscosity measurements of food and beverage products help maximize both production and process-ability efficiency and ensures a consistently high quality of the product. This paper presents and reviews a survey of conventional viscometers and rheometers used and pre-sented in markets, comparing their efficiency with new technology and sensing methods for viscosity measuring of food products. The paper concludes by reviewing the new approach to a tiny and porta-ble device as a friendly user, accurate with low cost to be equivalent to the laboratory measurements efficiency.

Keywords: Viscosity Monitoring; Mobile Food Scanners; In-Line Sensors

Introduction

Viscosity is one of the most important internal physical qualities to consider when analyzing liquid behavior and fluid motion for any application, it is defined as a fluid's resistance to flow which is essential for detecting food authenticity, contamination, freshness, and consumption. When a material's properties, such as molecular weight and density, vary, the viscosity of food changes, leading to unique functional products, and therefore the quality is altered [1]. It has been demonstrated that viscosity can affect its retention on tooth surfaces and oral clearance, particularly in 3-6-year-old children, where milk and dairy products are the most frequently consumed food products, which must be determined prior to consumption. Furthermore, viscosity can be considered a risk factor for evaluating the relationship between food retention and dental caries [2]. Additionally, research revealed that the viscosity of a semi-solid food effects postprandial metabolism and nutritional bioavailability by affecting eating and stomach emptying rates, and that long-term adjustment of rheological characteristics of diet influences the risk of chronic diseases [3]. Hence, it is necessary to detect and monitor the viscosity of food products that deal with the flow and deformation of foods in real-time. The most popular techniques to represent viscosity are dynamic and kinematic. Dynamic viscosity provides information on the force required to make the fluid flow at a certain rate [4]. If this is of interest, the mechanical stress that can be explained in terms of dynamic viscosity is more suitable for understanding the intermolecular interaction. Due to the simplicity of kinematic viscometers, it has been more convenient when the interest is the fluid motion and velocity field since it carries information about the propagation of movement by friction [5]. Most «kinematic» viscometers use gravity to drive the fluid flow. Moreover, take into consideration, not all fluids behave in the same way, there are two types: Newtonian and Non-Newtonian behaviors. Simple liquids with tiny molecules that do not interact or create any linked structure exhibit Newtonian behavior. However, it must be pointed out that long-chain polymers at low concentrations can also show Newtonian behavior. An easy way to demonstrate Newtonian behavior is to double the shear stress during a viscosity test, which should result in doubling the shear rate. In Newtonian fluids, the viscosity remains constant, regardless of changes to the shear rate [1,6].

Examples of typical Newtonian fluids include, water, filtered depectinized juices, refined vegetable oils, sugar syrup, and wines [7]. But, in non-Newtonian fluids, the viscosity fluctuates. These fluids in-clude these types: solutions of biopolymers (also called gums and hydrocolloids), chocolate, starch dispersions, baby foods and other pureed fruit ´ and vegetable products, orange juice, tomato juice, paste and concentrate, mustard, mayonnaise, salad dressing, concentrated milk, and yoghurt [7]. Non-Newtonian fluids has shear thinning properties because its viscosity decreases as you increase the shear stress [8]. Fluids with larger, more complex, molecules will have higher viscosities. This is particularly true for the long chain polymers that are found in foods such as proteins, starches, hydrocolloids, or gums, etc. Another striking property of these materials is that they consist of numerous chemical groups (hy-droxyl groups, anionic groups etc.) along the length of the polymer chain that are water loving or hy-drophilic and hence can bind water molecules. The polymer chains can also become entangled with one another, forming networks that are able to trap and immobilize water [9]. There are many different methods and instruments used for measuring the viscosity of food and bev-erage products have been reported in the literature. In Table1 we have explored the fundamental and common measuring devices for obtaining the dynamic and kinematic viscosity of fluidic samples [10-22]. Those traditional devices are the most frequently used viscosity measuring devices, viscometers and rheometers are very valuable in the food manufacture, which can deliver very precise results, it help food scientists in, evaluating the technological properties of food/liquid suspensions at different particle sizes, pH, concentration of ionic compounds, for instance, [23] measuring the viscosity of batters (non-Newtonian materials) to assess the stability of the dispersed phases within the system to different mixing regimes, mixing temperatures, concentration of hydrocolloids, floor times and baking tempera-tures, and predicting the pumpability, heat transfer and heat penetration properties for thermal pro-cessing of liquid foods, monitoring the viscosity of jams and syrups in the production of food condi-ments, to ensure batches are consistent, and analyzing milk's flow properties when designing piping systems for it [24].

Table 1: Survey of Viscosity Sensing devices for Food Safety present on the market.

	Methods	Requirements	Outputs	Applications	References
KINEMATIC VISCOSITY	Capillary U-tubes Viscometer	-Submerging the glass tube in a temperature-controlled bath, usually at 40 or 100°C.	- Mesure The time taken for the liquid to flow through the capillary section of the viscometer, from one marker line to the other, using gravity -A precise time reading, measured in seconds. - Often find a capillary viscometer in a laboratory setting	- Suitable for low viscosity fluids such as oils or tomato serums, but is not a realistic measurement technique for higher viscosity fluids -Measuring kinematic viscosity in applications such as asphalts, lubricants and fuels, paints, and polymers.	[10-12]
	Orifice viscometers	--	- A cup is filled by dipping it into the fluid and withdrawing it. A stopwatch is started as soon as it is withdrawn and stopped when the first break occurs in the issuing stream. -The time for a standard volume of fluid to flow through an orifice is measured.	- Simple, inexpensive, rapid method	[13]

DYNAMIC VISCOSITY	Rotating viscometer	-Remain a specific gravity of the fluid constant during the trending period. -Information to be logged includes the spindle number, rpm speed, sample temperature, and volume. -Keep track of the percent torque and the specific gravity of the fluid. -Measurement occures at room temperature.	-Measures the torque required to rotate an immersed cylindrical or disc spindle in a fluid product, by measuring the resistance of the material to the stirring action of the spindle which is driven by a motor to obtain a certain number of revolutions per unit time.	-Oil analysis - Used for quality control purposes as it allows detection of change in viscosity due to any perturbation during processing	[14-16]
	Falling Ball /Piston Viscometers	-The terminal velocity, size and density of the ball or piston you are using must be known. -Repeating the process to establish an average will provide the best results.	-Measure the time between marked points when a ball or piston falls into the liquid, using the force created by a falling piston/ball.	-Related to the food industry (sugar solutions, honey, beer, milk, gelatin, fruit juices). - Can also measure the viscosity of gases.	[17,18]
	Vibrational Viscometer	-Monitoring power input, the decay time of oscillations, or changes in the resonated frequency.	-Measure the resistance of a fluid to vibration, by applying oscillating vibrations to the sample and monitoring the damping effects of the fluid	- Used for measuring gelation of pudding and Jell-O	[19]
	Rheometers	-Consider the specific testing conditions such as % concentration of solids in sample or solution, shear rate and temperature	-Used for viscoelastic characterization of fluids under a known flow field. -Exert some type of shear force upon the fluid being tested and measure the results of this stress yields	- Measure non-Newtonian fluids	[20-22]

Furthermore, a diverse range of industries and sectors of applying viscosity measurements include, pharmaceutical, biotech and clinical research, chemical, beauty and cosmetics, environmental testing, petrochemical and oil [25]. However, in both rheometric and viscometry measurements, a large sample volume and a long measurement time are required. Working conditions are usually considered for sample conditions and pretreatment (constant flow, laminar flow, and constant temperature), since it can influence meas-urement results [23]. These viscometers can measure the viscosity in macroscopic materials but are insufficient for microscopic materials [26]. Researchers have exploited other techniques and sensing methods for viscosity detection for food quality control, listed in Table 2 [27-42]. Most of those techniques are laboratory-based measurement, the cost of viscometry measurements becomes very high since they require substantial labor contribution and need a qualified laboratory assistant. Furthermore, these methods generally involve direct contact with a liquid sample that is being measured, which is often undesirable, because the food sample can be easily contaminated during every point of production or processing. Hence, hygienic/food safety must be considered throughout the whole food supply chain, as it is directly related to the health of consumers whether they are buying canned food or dining in a restaurant [43]. Also, another issue of careful use of food and dumping due to the expiration of the product is getting more popular. Product quality depends not only on the capability and safety of the process and preventive measures but also on the quality of the equipment used, because in many cases washing process can be poor quality, which leads to distortions in measurement results.

Table 2: Survey of Viscosity Sensing Methods for Food Safety.

Technique	Instruments	Application	Advantages/Outputs	References
Microfluidic viscosity sensor based capacitive readout	Screen printed electrode (PET sheet printed with silver ink) coated with PMMA (poly(methyl methacrylate) and BaTiO3 (barium titanate)	-Water/glycerol mixtures	-Suitable for measurement of liquids with a low viscosity - Up to 10 mPa.s can be measured easily	[27]
Micro-acoustic viscosity sensor	AT-cut quartz blank using chromium/gold layers for the structure, integrated heater and temperature sensor and counter-electrode	- Mineral oils	-Requires less heating power and yields shorter measurement -Requiring small sample volumes -The temperature of the liquid sample can be easily controlled directly at the sensitive surface	[28]
Organic piezoelectric resonators	2 Electrodes: Polyethylene naphtalate (PEN) serves as substrate coaed with polyvinylidene fluoride-trifluoroethylene (PVDF- TrFE), and Polydimethylsiloxane (PDMS) layer	- Water-glycerol mixtures	-Simple and low-cost fabrication process from - Measure until 80 mPa.s	[29]
Electromechanical impedance (EMI) of a piezoelectric torsional transducer	- Stainless steel substrate: thin-wall tube- a solid connector and a solid sensing rod- piezoelectric ceramic (PZT-5H) patches	- Glycerol-water solutions	- Promising for online measurement, -From 20 mPa.s to 700 mPa.s -Relative measurement errors are within 10%	[30]
Measurement device based fluorescence and transmittance light	Hall effect sensors-fluorophore, optical fiber-excitation LED	-Water	-Online measuring technique with inexpensive components -Control for many parallel samples	[31]
Viscosity sensor based fluorescence intensity and life time	Photomultiplier tube as detector- Fluorolog-3 spectrometer with 450W CW Xe-lamp- fluorescent probe: HNPs: sensor based hybride nanoparticles: Eu(TTA)3Phen (ETP) coordination compound and fluoride nanoparticles	-Glycerol-water medium	-Fluorescence intensity and life-time both have detected -Viscosity range from 1 to 1410 mPas	[32]
Photoelectrical viscosity sensing	-Organic photosensor with coplanar electrodes	- Glucose as the solute	-Measure in short time - From 0.9–10 mPa·s) -Able to measure low viscosities in nonelectrolyte aqueous solution	[33]
Inline Acoustic Flowmeter at Laboratory Scale	-IDT sensors: Interdigital transducer deposited on the surface of a piezoelectric substrate (e.g., quartz, lithium tantalite)	Milk	-Offline viscosity value = 0.97 and standard -Error of prediction = 1.86 mPa·s	[34]

Fluorescence detection of viscosity	-Near-infrared fluorophore based on tetranitrile-anthracene (TPAEQ) was designed for viscosity determination via aggregation-induced emission (AIE) used as probe sensor	Jasmine tea juice and Kaman orange juice	-Good photostability -Enable the on-site direct detection	[35]
Sensor based piezoelectric material	- Piezoelectric sensor and actuator device pair based on a tuning fork principle using an actuator sensor pair.	Glycerin and water	- Low-cost and tiny device	[36]
Ultrasonic waveguide sensor	-Sensor: planar waveguide: (1) pipe; (2) aluminium planar waveguide; (3) sealing; (4) ultrasonic transducer-transmitter; (5) ultrasonic transducer-receiver.	Viscous liquid	-Range from 20 Pa·s up to 27,000 Pa·s. -Mechanically robust sensor and suitable for in-line	[37]
Resonant MEMS sensor	-Sensor: plate for vibrations and piezoresistive readout on a silicon-on-insulator (SOI) wafer	Glycerol–water mixtures	-Viscosity range below 100 mPas -Can be utilized for viscosity of arbitrary liquids	[38]
Fluorescence Spectroscopy	-Diode laser, a high-pass filter, three biconvex lenses, a multi-mode fiber, and a fiber-optical spectrometer.	Yogurt	- Good linear relationship with an R-square of more than 85%	[39]
Microscopic viscosity Using Fluorescent Molecular Rotors	-Fluorescent probes based on a 4,4-difluoro-4-bora-3a,4adiaza-s-indacene (BODIPY) core0 0used as rotor-laoratory setup	Viscous liquid	-Good dynamic range of the viscosity-sensitive fluorescence lifetime (3–1000 mPas)	[40]
Optical sensor utilizing a forward light scattering pattern	He-Ne linearly polarized laser and a single mode optical fiber probe, bimorph piezoelectric transducer; PIN diode detector	Glycerin-water solution	-For high viscous solution 52% GWS is 0.29 mPa·s (1.02 mPa·s).	[41]
IN-line Resonant Steel Tuning Fork	An electromagnet, used for excitation, placed close to the end of the ferromagnetic tuning fork, welded to a solid stainless steel stand. At the end of the second prong, a copper coil	Viscous liquid	-Repeatability of better than 1 % -Viscosity range of 0.2 mPa·s to 2 mPa·s	[42]

The efficiency of cleaning procedures is also highly dependent on the design of equipment used, there are some measurement techniques that suffer from the wear-out issue of sensors for contacting measurement, for instance, a tuning fork, has a design, that is difficult to clean and difficult to free from micro-organisms, therefore, increase the risk of post contamination. New technologies for measuring viscosity, have recently been reported using mobile applications and portable, tiny, wireless-based devices for viscosity measurement, such as: Z. B. Suleimenov et al. have proposed a viscometer system using a smartphone, the technology is based on a known method of viscosity measurement through defining characteristics of ball movement in a viscous environment, but setting by an external magnetic field., the processing of primary measurement signals and control of the measurement process is carried out using software installed on user's smartphone. the advantages of the proposed type of viscometer are the simplicity of technical implementation since this device can be assembled on standard components (microcontroller and Bluetooth module) and this allows to significantly reduce the cost of equipment [44]. As a comparison, non-contact measurement is faster than contact measurement, especially for applications with high sampling rates, and can also measure more points at one time and without putting pressure on the object. They are also less prone to sensor wear and won't dampen the motion of a target. Although non-contact system has its advantages, contact-based measurement is a good choice for applications with low levels of cleanliness. Contact devices are also recommended for measuring exterior features that are not visible to non-contact devices.

Figure 1 shows the main advantages and constraints of the traditional techniques in comparison with the mobile and in-line equipment for continuous and instantaneous monitoring of the food products properties. Eguchi et al. have developed a new type of non-contact optical and fast in-situ hand-held viscometer-based on a laser-induced capillary wave sensing method with incident angle and irradiation timing controls, where the experimental results confirmed the applicability of the system and provided high stability under hand-held conditions. The device also requires much smaller sample sizes compared to standard measurement methods, once again lending itself to mass-production applications. The obtained results of viscosity were 0.6 mPa·s above the heater at lower parts was calculated to be around 1.3 mPa·s. And 2.8 mPa·s at room temperature [45]. Those new concepts have the advantage of being used as a simple versatile detection application, where the quantification could also be done with a simple smartphone App, or a tiny handheld device without needing an expert, and could be one of our everyday uses, which allows signal analysis to be performed by untrained users without laboratory equipment. In accordance with the basic ideas of the Internet of Things concept [46,47], improvement of information and communication technologies allows eliminating all such factors by software means only (for example, to user's smartphone computation power). In summary, we explored and criticized the SoA for mobile/inline devices for the viscosity measurement of food products. Recent advances in the field have made it possible to achieve sensitive and specific detection of food quality control using handheld and mobile/inline sensing application, however, even in an embodiment not meeting SoA desktop instrumentation quality can substantially enhance the sensorial fingerprint of a tiny mobile food scanner to efficiently monitor food quality, at an affordable cost.

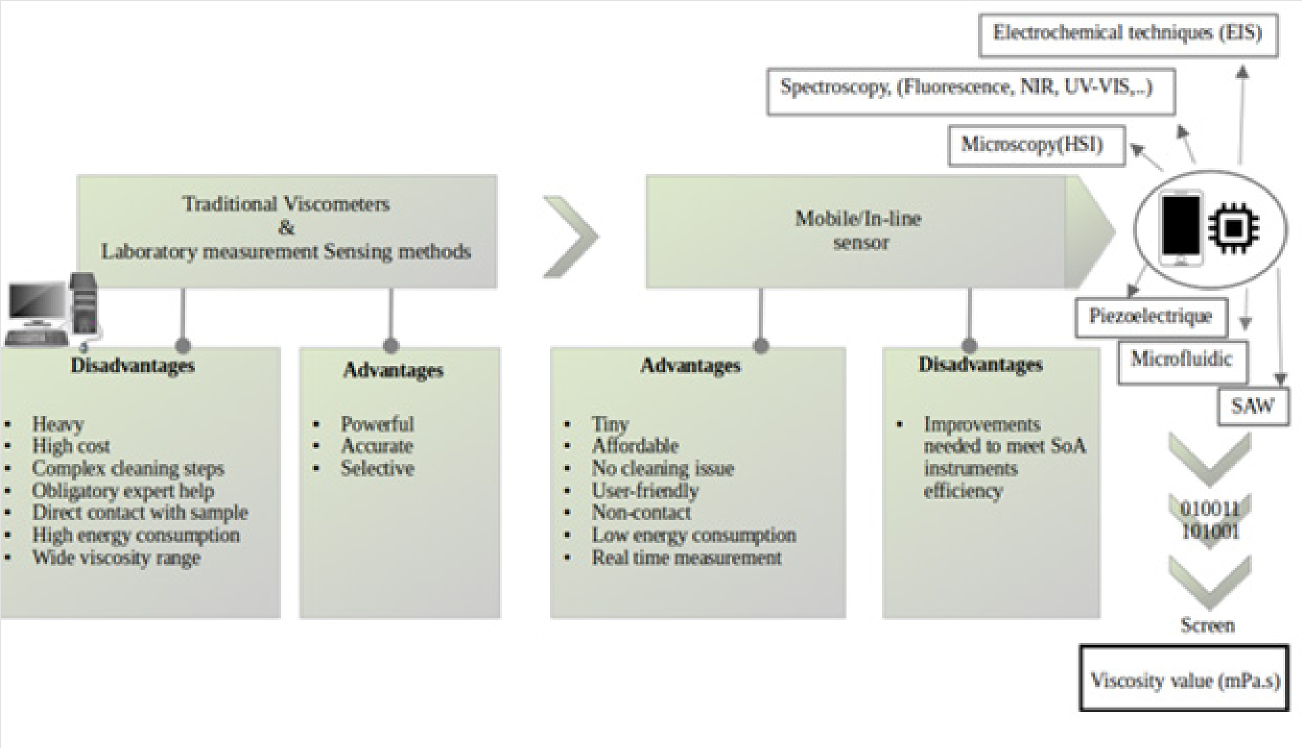

Figure 1: Comparison for desktop versus integrated approaches.

Emerging microscopic with light scattering technologies (e.g. Raman micsoscopy) which don't feature viscosity sensing yet, will be capable of offering direct contact with the sample, with no expert/ assistant need, and measuring the viscosity in a large range with an accuracy range of ±1% to ±0.2%. Thus, a novel handheld sensing device should implement the multi-sensory and ML-technique for continuous and instantaneous monitoring of a product's properties to further approach SoA laboratory equipment.

References

1. Sahin S, Sumnu SG (2006) Physical Properties of Foods. FoodScience Text Series, Springer, USA.
2. Neeraja G, Subramaniam P, Kumar S (2018) Assessment of physical properties of foods commonly consumed by children. Saudi Journal of Oral Sciences 5(1): 41.
3. De Villiers M, Hanson B, Moodley L, Pillay M (2020) The impact of modification techniques on the rheological properties of dysphagia foods and liquids. J Texture Stud 51(1): 154-168.
4. (2003) Engineering ToolBox. Viscosity - Absolute (Dynamic) vs. Kinematic.
5. Engineer Ramiz (2020) Dynamic vs Kinematic Viscosity: its 9 Differences, & Formula.
6. Bourne M C (2002) Food Texture and Viscosity: Concept and Measurement (2nd Edn.)., Academic Press, San Diego.
7. Meyers R A (2016) Encyclopedia of Analytical Chemistry: Applications, Theory and Instrumentation, Supplementary Volumes S1-S3. Analytical Chemistry.
8. Rao M A (2006) Viscosity of food: measurement and application. Encyclopedia of Analytical Chemistry: Applications, Theory and Instrumentation.
9. Sarab Sahi (2014) Viscosity measurements in food products and manufacturing.
10. Cho YI, Kim W T, Kensey K R (1999) A new scanning capillarytube viscometer. Review of Scientific Instruments 70(5): 2421-2242.
11. Kim S, Cho YI, Kensey K R, Pellizzari, Stark P R H (2000) Ascanning dual-capillary-tube viscometer. Review of Scientific Instruments 71(8): 3188-3192.
12. Shin S, Lee S, Keum D (2001) A new mass-detecting capillaryviscometer. Review of Scientific Instruments 72(7): 3127-3128.
13. Stabik J, Dybowska A, Szczepanik M, Suchon L (2009) Viscositymeasurements of epoxy resin filled with ferrite powders. WorldAcademyof Materials and Manufacturing Engineering 38(1): 34-40.
14. Gomez-Diaz DG, Navaza J (2004) Rheology of food stabilizersblends. Journal of Food Engineering 6(4): 143-149.
15. Dutta D, Dutta A, Raychaudhuri U, Chakraborty U (2006) Rheological characteristics and thermal degradation kinetics of beta-carotene in pumpkin puree. Journal of Food Engineering 76(4): 538-546.
16. Rao M A, Cooley H J (1984) Determination of effective shearrates in rotational viscometers with complex geometries Journal of TextureStudy 15(4): 327-335.
17. Yanniotis S, Kotseridis G, Orfanidou A, Petraki A (2007) Effect of ethanol, dry extract and glycerol on the viscosity of wine. Journal ofFood Engineering 81(2): 399-403.
18. Patrignani F, Vannini L, Kamdem SLS, Lanciotti R, Guerzoni M, et al. (2009) Effect of high-pressure homogenization on Saccharomycescerevisiae inactivation and physico-chemical features in apricot andcarrot juices. International Journal of Food Microbiology 136(1): 26-31.
19. AKPEK A, YOUN C, Kagawa T (2014) A study on vibrational viscometers considering temperature distribution effect. JFPS International Journal of Fluid Power System 7(1): 1-8.
20. Alas Bringas C, Jeksrud WK, Schuller RB (2007) A new on-lineprocess rheometer for highly viscous food and animal feed materials.Journal of Food Engineering 79(2): 383-391.
21. Roberts I (2001) In-line and on-line rheology measurement. In: Kress-Rogers, E. and Brimelow, C. J. B. (Eds.)., Instrumentation and Sensorsfor the Food Industry. CRC Press, Boca Raton FL, pp. 403-42.
22. Salas C (2004) Development of an On-line Rheometer and Die Testerfor Feed/Food Quality Control. PhD. thesis, Norwegian University ofLife Sciences, p. 84.
23. Bourne M C (2002) Concept and measurement. Food texture and viscosity.
24. Cullen P J, Duffy A P, O Donnell C P, O callaghan D J (2000) Process viscometry for the food industry. Trends in Food Science & Technology 11(12): 451-457.
25. Monoclonal Antibodies (2015) Viscometer an overview, ScienceDirect Topics.
26. Abbas K A, Abdulkarim S M, Saleh A M, Ebrahimian M (2010) Suitability of viscosity measurement methods for liquid food variety and applicability in food industry-A review. Journal of Food, Agriculture, & Environment 8(3): 100-107.
27. M A Hintermüller, C Offenzeller, B Jakoby (2021) 'A Microfluidic Viscometer with Capacitive Readout Using Screen-Printed Electrodes', IEEE Sens J 21(3): 2565-2572.
28. B Jakoby, F P Klinger, P Svasek (2005) 'A novel microacoustic viscosity sensor providing integrated sample temperature control', Sens. Actuators Phys 123-124: 274-280.
29. PH Ducrot, Isabelle Dufour, Fabrice Mathieu, Liviu Nicu, Martin Heinisch, et al. (2021) 'Simple fabrication process for organic piezoelectric resonators: application to viscosity measurement', Delft, Netherlands, Jun. 2016.
30. G Wang, F Li (2018) 'An Online Viscosity Measurement Method Based on the Electromechanical Impedance of a Piezoelectric Torsional Transducer', IEEE Sens J 18(21): 8781-8788.
31. M Sieben, R Hanke, J Büchs (2019) 'Contact-free determination of viscosity in multiple parallel samples', Sci. Rep, vol. 9, no. 1, Art. no. 1.
32. P K Shahi, R Prakash, S B Rai (2020) 'Impact of viscosity on photo-induced bimodal emission, decay profile and energy transfer in lanthanide-based hybrid nanostructure', Opt. Mater 107: 110086.
33. Z Su, Rui Feng, Laigui Hu, Hanqiu, YiCheng, Chen, et al. (2018) 'Organic semiconductor/water interfaces for photoelectrical viscosity sensing', Electrochemistry Communications 95: 18-22.
34. Bista A, Tobin JT, O Donnell C P, O Shea N (2020) Monitoring Viscosity and Total Solids Content of Milk Protein Concentrate Using an Inline Acoustic Flowmeter at Laboratory Scale. Foods 9(9): 1310.
35. Xu L, Ni L, Zeng F, Wu S (2020) Tetranitrile-anthracene as a probe for fluorescence detection of viscosity in fluid drinks via aggregation-induced emission. Analyst 145(3): 844-850.
36. Abdulkareem A, Erturun U, Mossi K (2020) Non-destructive evaluation device for monitoring fluid viscosity. Sensors 20(6): 1657.
37. Kazys R, Sliteris R, RaisutisR , Zukauskas E, Vladisauskas A, et al. (2013) Waveguide sensor for measurement of viscosity of highly viscous fluids. Applied Physics Letters 103(20): 204102.
38. Cerimovic S, Beigelbeck R, Antlinger H, Schalko J, Jakoby B, et al. (2012) Sensing viscosity and density of glycerol–water mixtures utilizing a suspended plate MEMS resonator. Microsystem technologies 18(7): 1045-1056.
39. Sun H, Wang L, Zhang H, Wu A, Zhu J, et al. (2019) Evaluation of yogurt quality during storage by fluorescence spectroscopy. Applied Sciences 9(1): 131.

40. Kubánková M, Summers PA, López-Duarte I, Kiryushko D, Kuimova M K, et al. (2019) Microscopic viscosity of neuronal plasma membranes measured using fluorescent molecular rotors: Effects of oxidative stress and neuroprotection. ACS applied materials & interfaces 11(40): 36307-36315.

41. Fedorchenko A I, Stachiv I, Ho J, Wang A B, Wang W C, et al. (2008) Optical viscosity sensor based on the partially immersed fiber vibrations. In Health Monitoring of Structural and Biological Systems 2008 (Vol. 6935: 637-647).

42. Heinisch M, Abdallah A, Dufour I, Jakoby B (2014) Resonant steel tuning forks for precise inline viscosity and mass density measurements in harsh environments. Procedia Engineering 87: 1139-1142.

43. Schleining G (2007) Preventive measures for food safety. In Food Safety (pp. 50-67). Springer, Boston, MA.

44. IE Suleimenov, S B Kabdushev, K Kadyrzhan, D B Shaltikova, I Moldakhan, et al. (2020) New Technologies for Measuring Viscosity: Using Mobile Applications. In Proceedings of the 2020 6th International Conference on Computer and Technology Applications (ICCTA '20). Association for Computing Machinery, New York, NY, USA, pp. 129-133.

45. Masato Eguchi, Yoshihiro Taguchi, Yuji Nagasaka (2018) "non-contact optical hand-held viscosity sensor with incident angle and irradiation timing controls," Opt Express 26(26): 34070-34080.

46. Jeschke S, Brecher C, Meisen T, Özdemir D, Eschert T, et al. (2017) Industrial internet of things and cybermanufacturing systems. In Industrial internet of things (pp. 3-19). Springer, Cham.

47. Ng I C, Wakenshaw S Y (2017) The Internet-of-Things: Review and research directions. International Journalof Research in Marketing 34(1): 3-21.

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