Sudan University of science and Technology

College of Graduate Studies

Use of x-ray fluorescence inNon Destructive Testing to determine Elements in Cheese

استخدام الاشعة السينية الطيفية في الكشف اللاإتلافي لمعرفة العناصر الموجوده فى الجبنة

Thesis Submitted in partial fulfillment of the
Requirements for the Master degree in Physics

By

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الآية

قال تعالي

(قُل لَّوْ كَانَ الْبَحْرُ مِدَادًا لِّكَلِمَاتِ رَبِّي لَنَفِدَ الْبَحْرُ قَبْلَ
أَن تَنفَدَ كَلِمَاتُ رَبِّي وَلَوْ جِئْنَا بِمِثْلِهِ مَدَدًا)

الآية (109) من سورة الكهف

Dedication

This work was dedicated to

my parents, my brothers and my sisters, my friends, my teachers, my colleagues.

Acknowledgement

✐First of all I thank my god (Allah)

I would like to express my appreciation and respect to to prof-Mubarak Dirar Abd-alla He strives to help me succeed.

My humble thanks are due to Petroleum Technical Center (ptc); from them I saw unlimited patience, unsparing guidance, and unfailing trust.

Abstract

A long time ago dairy products play an important role in the diets for.
Most of the people, so it is necessary to pay attention to diet safety healthy core. Interest is increased in XRF device for it is perfectness and it is important role. In this research cheese samples from different places in Sudan and abroad to determine concentration of elements by using x-ray fluorescence (XRF) spectrometer. The analysis shows that the concentration of heavy elements like pb, Cr and Zn are less than 0.04%.

الملخص

منذ زمن بعيد تعتبر منتجات الالبان تلعب دوراً مهماً في الوجبات الغذائية الرئيسية عند اغلب الشعوب لذا كان لابد من الاهتمام بالالبان ومنتجاتها وسلامتها لسلامة تناولها ولتعزيز الجانب الصحي.

زاد الاهتمام في الآونة الأخيرة بجهاز مطياف الاشعة السينية التوهجي XRF لدقته ودوره مهم . في هذا البحث تم تحليل عدة عينات من منتجات الجبنة من مناطق مختلفة في السودان وأخري من خارج السودان لتحديد تركيز العناصر في هذه العينات باستخدام جهاز مطياف الاشعة السينية التوهجي وأوضح التحليل بجهاز مطياف الاشعة السينية الطيفية ان تركيز العناصر الثقيلة مثل الرصاص والكروم والزنك اقل من 0.04% .

Contains

Chapter Three: Practical work

Chapter 1

Chapter1:Introduction

(1-1) X-ray spectroscopy:

Material tests had known for a long time. Some specimen's destruction in order to understand structural performance or material behavior under different loads, this type of testing are called destructive physical analysis tests. They have many forms (stress tests bend, strike, hardness and crash tests).

Recently other types of testing which is Non destructive testing (NDT) classified as an invasive technique, plays an important role in assuring that structural and mechanical component perform their function in a safe, reliable and the cost-effective manner, with several ways .[1]

One of non destructive testing methods is x-ray fluorescence which is a proven technique for material analysis in a broad range of industrial and applications. The idea of XRF is to excite elements under investigation to fluoresce, where both the activating and the emitted light quantum, or photon, is in the X-ray energy spectrum. [2]

Each element emits a photon of a certain energy and frequency different from all photon energies emitted by the rest of elements It is a well established and powerful tool for nondestructive elemental analysis of any material. It is widely used for environmental, industrial, pharmaceutical, forensic, and scientific research applications to measure the concentration of elemental constituents.

XRF analysis is a powerful analytical tool for the petrochemical Determination of almost all the elements present in a sample. XRF radiation is induced when photons of sufficiently high energy, emitted from an X-ray Source, impinge on a material. These primary X-rays undergo interaction processes with the analysis atoms. High-energy photons induce ionization of inner shell electrons by the photoelectric effect and thus electron vacancies in inner shells (K, L, M, …) are created. The prompt transition of outer shell Electrons into these vacancies within some 100 femto- second can cause the emission of Characteristic fluorescence radiation. Not all transitions from outer shells or subshells are allowed,[3] only those obeying the selection rules for electric dipole radiation are permitted. The creation of a vacancy in a particular shell results in a cascade of electron transitions, all correlated with the emission of photons with a will defined energy corresponding to the difference in energy between the atomic shells involved. The family of characteristic X-rays from each element including all transitions allows the identification of the element.[12]

Other interaction processes, mainly the elastic and inelastic scattering of the primary radiation on sample and substrate, induce the background. Measurement of the spectrum of the emitted characteristic fluorescence radiation is performed using wavelength dispersive (WD) and energy dispersive (ED) spectrometers. In wavelength dispersive X-ray fluorescence analysis (WDXRF), the result is an intensity spectrum of the characteristic lines versus wavelength measured with a Bragg single crystal as dispersion medium while counting the photons with a Geiger-Müller, a proportional or scintillation counter. In energy dispersive X-ray fluorescence analysis (EDXRF), a solid-state detector is usedto count the photons, simultaneously sorting them according to energy and storing the result in a multichannel memory. The result is X-ray energy vs. intensity spectrum. The range of detectable elements ranges from be ($Z = 4$) for the light elements and goes up to U ($Z = 92$) on the high atomic number Z side. The concentrations that can be determined with standard spectrometers of WD or ED type lie are situated in a wide dynamic range: from the percent to the μg/g level. In terms of mass the nanogram range is reached with spectrometers having the standard excitation geometry.[4]

By introducing special excitation geometries, optimized sources and detectors, the picogram and even femtogram range of absolute analysis detection capacity can be reached; in terms of concentrations, the same improvement factor can be attained, i.e. from the µg/g towards the pg/g level under the best conditions.

In principle, XRF analysis is a multielement analytical technique and in particular, the simultaneous determination of all the detectable elements present in the sample is inherently possible with EDXRF. In WDXRF both the sequential and the simultaneous detection modes are possible.[5]

The most striking feature of XRF analysis is that this technique allows the qualitative and quantitative analysis of almost all the elements (Be–U) in an unknown sample. The analysis is in principle nondestructive, has high precision and accuracy, has simultaneous multielement capacity, requires only a short irradiation time so that a high sample throughput is possible; online analysis is also possible and the running costs are low. The technique is extremely versatile for applications in many fields of science, research and quality control, has low detection limits, and a large dynamic range of concentrations covering up to 9 orders of magnitude. The physical size of an XRF spectrometer ranges from handheld, battery-operated field units to high power laboratory units with compact tabletop units and larger ones requiring several cubic meters of space including a 10–20 kW electrical power supply and efficient cooling units with high pressure water and a heat sink. In contrast to all these attractive properties there are some disadvantages.

The absorption effects of the primary radiation and the fluorescence radiation created in the analyte result in a shallow layer a few tenths of a millimeter deep that provides information on its composition. This requires a perfectly homogeneous sample which often occurs naturally but must sometimes be produced by acid dissolution into liquids or by grinding and the preparation of pressed pellets. In both examples the feature of non-destructiveness is lost.

Most ideally thin films or small amounts of microcrystalline structure on any Substrate are the ideal analyze where also the quantification process is simple because there is linearity between fluorescence intensity and concentration. In thick samples corrections for absorption and enhancement effects are necessary. While the roots of the method go back to the early part of this century, where electron excitation systems were employed, it is only during the last 30 years or so that the technique has gained major significance as a routine means of elemental analysiSpectrometer systems are generally divided into two main groups Energy dispersive system (EDXRF) and wavelength dispersive systems (WDXRF). The difference between the two systems is found in the detection systems. EDXRF spectrometers have a detector the able to measure the different energies of the characteristic radiation coming directly from the sample. The detector can separate the radiation from the sample in to the radiation from the elements in the sample. This separation is called dispersion. WDXRF spectrometers use an analyzing crystal to dispersive the different energies. ALL radiation coming from the sample falls on the crystal. The crystal diffracts the different energies in the different direction

Qualitative analysis followed by Quantitative analysis. Qualitative Analysis determines which elements are present and their net intensities from the measured spectra[5].

(1-3) Research problem:

Although XRF analysis is powerful tool for determination of concentration of elements in sample, but it is not widely used in Sudan. Strictly speeding, it is used rarely in food analysis, to make sure that it is free form contamination.

(1-4) Literature Review:

Different attempts were made to use XRF analysis to determine concentration of elements [Mn,CU,Cr,Fe,Ni,Zn,Pb].[6]

Some researchers also used this technique to determine the concentration of the elements in vegetables or cares [Mn,Cu,Cr,Fe,Ni,Zn,Pb].

It is also used to determine impurities and contaminant can concentration [Mn,Cu,Cr,Fe,Ni,Zn,Pb].[7]

(1-4) Aim of the work

The aim of this work to determine the concentration of metals and some vital elements in a lot of cheese

(1.5) Layout of the research

The first chapter explains introduction in x-ray spectroscopy, research problem, literature review, aim of the work. In chapter two x-ray properties, generation, physics of fluorescence technique, the last chapter records the experimental equipments and sample preparations and experimental procedures and results of experimental work and discussion.

Chapter 2

Chapter two: X-ray fluorescence analysis

(2-1)introduction

This chapter is concerned with the physics of XRF, Also concentrates and the XRF spectrometer and the techniques used to determine concentration of elements

(2-2) X-rays properties

X-rays are form of electromagnetic radiation. They occur in the region of the electromagnetic Spectrum between 0.01nm & 10 nm so is bounded on the short wavelength side by Gamma rays and on the long wave length side by Ultra-Violet radiation.X-ray radiation has both a wave and a corpuscular (particle –like) character, X-rays were discovered in 1895 by Wilhelm Conrad Rontgen, who received the first Nobel Prize in Physics in 1901.the properties of these X-rays were investigated, and by 1912 the principles of diffraction physics and reciprocal space were developed by Rontgen, on Laue, Ewald and Summered .

The Name of X-rays is suggested by Roentgen because their nature was unknown at that time, unlike ordinary light, X-rays are invisible, they travel in straight lines and affects .they are much more penetrating than light and could easily pass through the human body, wood, metal etc.Exponentially absorbed in matter with the exponent proportional to the mass of the absorbing material and they are not affected by the magnetic field.

X-rays emitted by sudden stoppage of the fast moving electrons. It can also be scattered with and without losing part of their energy (coherent or Raleigh-scatter and incoherent or Compton - scatter).When an electron from the inner shell of an atom is lost due to some sort of excitation, it is replaced with an electron from the outer shell; the difference in energy is emitted as an X-ray photon which has a wavelength that is characteristic for the element (there could be several of characteristic wavelengths per element). Analysis of the X-ray emission spectrum produces qualitative results about elemental composition of the specimen. Comparison of spectrum of the specimen with spectra of standards of known composition produces quantitative results (after some mathematical corrections for absorption, fluorescence and atomic number).[8]

When X-ray beam passes through matter, some photons will be absorbed inside the material or scattered away from the original path. Most modern stand-alone X-ray spectrometers use X-ray excitation sources rather than electron excitation. All conventional X-ray spectrometers comprise three parts: the primary source unit, the spectrometer itself and the measuring electronics. An X-ray detector is a transducer for converting X-ray photon energy into easily measurable and countable voltage pulses. All detector types work through a process in which interaction between the entering X-ray photon and the active detector material produces a number of electrons.[9]

(2-3) Production of x-ray:

There are two known types of x rays: characteristic radiation and bremsstrahlung. Both types of x rays are important in medical physics, since both are used extensively in diagnostic imaging and in external beam radiotherapy .Characteristic x-rays are produced by electronic transitions in atoms triggered by vacancies in inner electronic shells of the absorber atom. Bremsstrahlung, on the other hand, is produced by Coulomb interactions between an energetic light charged particle and the nucleus of the absorber atom. When very fast electrons strike atoms they are decelerated. Thus it can emit electromagnetic radiations according to Maxwell's electromagnetic theory. The kinetic energy of the stopped electron is converted to photon energy. An X-ray tube consists of two electrodes, one negative, and glow cathode, which upon being heated emits electrons, and one positive, anode. The electrodes are capsulated in a vacuum. By applying an acceleration potential (20-200 kV), the electrons are accelerated towards the anode. The electrons gain kinetic energy which is the product of their charge and the potential difference. When the electron reaches the anode it imparts the main part of its energy to the atoms of the anode by ionizations and excitations.[1] This energy will finally appear as heat energy. If an electron passes close to an atomic nucleus, it will change its direction of motion, i.e., exhibits an acceleration. At each such acceleration there is a small probability that the electron looses energy in the form of a photon, These photons are called bremsstrahlung photons and constitute the main part of the X-rays being used in X-ray diagnostic imaging.Bremsstrahlung is generated when an electron with high energy changes it's Direction of motion in the neighborhood of an atomic nucleus and thereby looses energy. The bremsstrahlung photon can obtain an arbitrary energy between zero and the whole oThe kinetic energy of the electron, T.The relative amount of bremsstrahlung emitted increases with increasing electron kinetic.

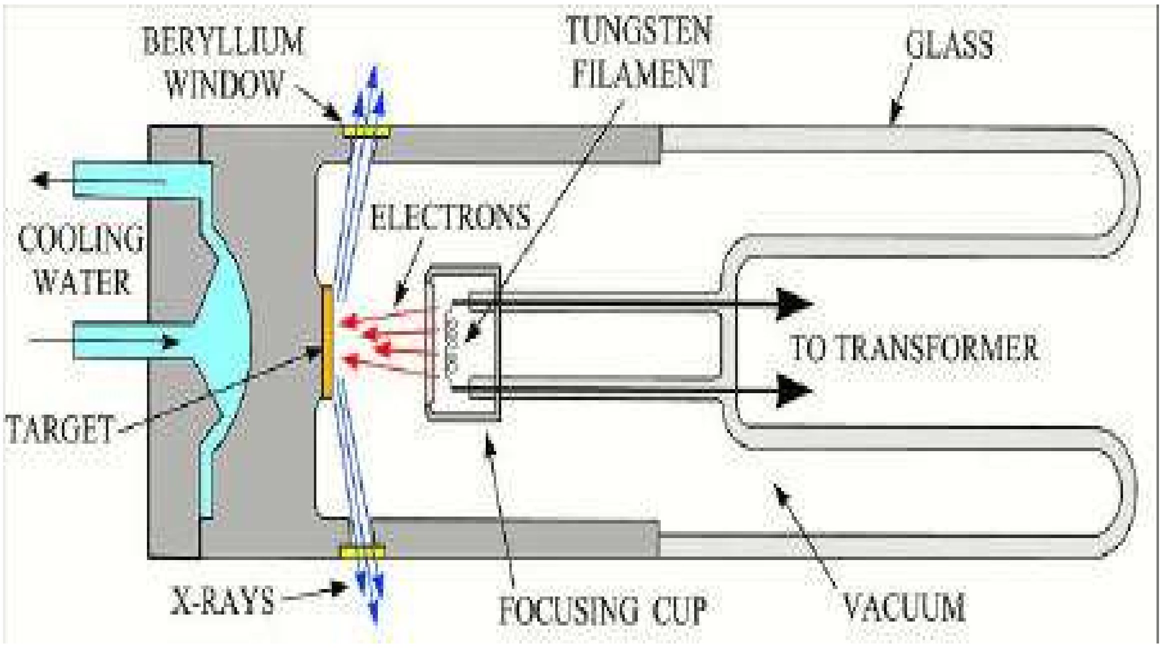
$$hf = T = \frac{1}{2}mv^2 = ev \text{ (2-3-1)}$$

Where:

h stander for blank const, f is the photon frequency ,m is mass, e is the electron charge and v is the accelerating potential of the butteryEnergy and with increasing atomic number, Z, of the anode material. Since the major part of the energy of the electrons is converted into heat in the anode(About 1% will appear as X-rays), the anode material should have high melting point and good heat conduction ability. To get a high relative amount of X-ray energy, the Anode material should be of high atomic number. Tungsten is the dominating anodeMaterial and is in modern X-ray tubes often mixed with rhenium (ZW=74; Z Re=75).

Modern X-ray imaging requires a small focal spot and high X-ray fluence rates (number of photons per unit area and unit time). To meet these requirements, technical solutions with a line shaped focal spot and rotating anode have been introduced.

X-rays are produced when electrically charged particle with a sufficient kinetic energy is rapidly decelerated. X-rays are generated in a cathode ray tube contains a source of electrons and two metal electrodes



Free electrons are produced by heating filament called the cathode to a high temperature by the passage of an electric current. Then, negatively charged particles are accelerated to high energy by applying a voltage of several tens of kilovolts between the filament and the target or a node. If the electrons have sufficient energy, x-rays are produced at the point of impact and emitted in all directions but only the x-rays making a certain angle is allowed to pass through the window. Most of the kinetic energy of electrons is converted to heat.

A target (composed of a metallic element and must be pure: **Cr, Fe, Co, Cu, Mo, Ag, etc).**The tube is cooled by water and housed in a shielding aluminum tower.In an x-ray tube, the interactions are between the electrons and the target. Since energy must be conserved, the energy loss from the interaction results in the release of x-ray photons. The energy (wavelength) will be equal to the energy loss .This process generates a broad band of continuous radiation.

Electrons traveling from the filament (cathode) to the target (anode) convert a small percentage (1%) of their kinetic energy into x-ray photons by the formation of bremsstrahlung and characteristic radiation, filament lamp, is of the spontaneous type.[10]

In bremsstrahlung interactions, the primary source of x-ray photons from an x-ray tube, are produced by the sudden stopping, breaking or slowing of high-speed electrons at the target. When the electrons from the filament strike the tungsten target, x-ray photons are created if they either hit a target nucleus directly (rare) or their path takes them close to the nucleus. If a high speed electron hits the nucleus of a target atom, all its kinetic energy is transformed into a single x-ray photon. (Total absorption has occurred). Thus, the energy of the resultant photon is numerically equal to the energy of the electron

Bremsstrahlung interactions generate x-ray photons with a continuous spectrum of energy.

(2-4)Characteristic Radiation:-

This radiation occurs when an electron from the filament displaces an electron from an inner-shell of the tungsten target atom, thereby ionizingthe atom. When this happens, another electron in an outer-shell of the tungsten atom is quickly attracted into the void in the deficient inner-shell. When the displaced electron is replaced by the outer-shell electron, a photon is emitted with an energy equivalent to the difference in the two orbital binding energies.

$$hf = E_2 - E_1 \quad (2-4-1)$$

Characteristic radiation from the K-shell occurs only above 70 kv with a tungsten target and occurs as discrete incrementscompared with bremsstrahlung radiation.

Characteristic radiation has a higher intensity, is preferred but is only a minor source of radiation from an x-ray tube.[11]

(2-5) Physics of x-ray Fluorescence

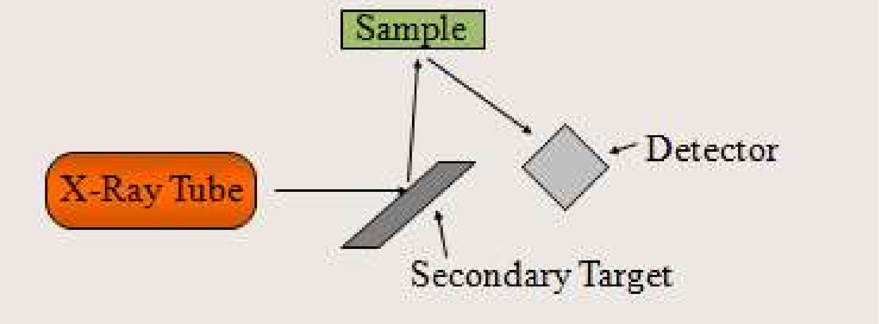
The name florescence was derived from the mineral fluorite (calcium difluoride). Fluorescence occurs when an orbital electron of a molecule, atom or nanostructure relaxes to its ground state by emitting a photon of light after being excited to a higher quantum state by some type of energy. The atom emits X-ray Fluorescence in the region 0.2–20 A.

Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation .in most cases; the emitted light has a longer wave length, and therefore lower energy than the absorbed radiation.

When the absorbed electromagnetic radiation is intense, it is possible for one electron to absorb two photons; these two absorption photons can lead to emission of radiation having a shorter wave length than the absorbed radiation. The emitted radiation may also be of the same wave-length as the absorbed radiation, termed (resonance fluorescence).

The fluorescence quantum yield gives the efficiency of the fluorescence process; it defined as the ratio of the number of photons emitted to the number of photon absorbed. Fluorescence has any practical applications, including mineralogy, geology, chemical sensors, cosmic ray detection, and practical analysis.[12]

The process of emissions of characteristic x-rays is called "X-ray Fluorescence" or XRF. Analysis using x-ray fluorescence is called "X-ray Fluorescence Spectroscopy." The main principle of X-Ray Fluorescence Spectroscopy (XRF) is based on the fact, that atoms, when irradiated with X-Rays, radiate secondary X-Rays – the Fluorescence radiation. X-rays need energy to pass through the material to be analyzed and to reach the detector or photographic plate.



On this basis XRF-analysis is possible because:

- The wavelength and energy of the Fluorescenceradiation is specific for each element.
- The concentration of each element can be calculatedusing the intensity of the Fluorescence radiation.

The optimum energy for X-ray beams depend on interaction cross section and on the nature (density) of material.

XRF analysis is a powerful analytical tool for the spectroscopic determination of almost all the elements present in a sample. XRF radiation is induced when photons of sufficiently high energy, emitted from an X-ray source, impinge on a material. High-energy photons induce ionization of inner shell electrons by the photoelectric effect and thus electron vacancies in inner shells (K, L, M …) are created. The creation of a vacancy in a particular shell results in a cascade of electron transitions, all correlated with the emission of photons with a well defined energy corresponding to the difference in energy between the atomic shells involved. The family of characteristic X-rays from each element including all transitions allows the identification of the element.

According to the Bohr model of an atom the electrons surrounding the nucleus are confined to different orbits, constituting so called electron shells at discrete energy levels, labeled K, L, M,…etc, and also further subdivided. The electrons in the K-shell are closest to the nucleus, and also the most tightly bound.

When an atom absorbs an incident photon which has an energy that exceeds an electron binding energy, it may result in the emission of a so called photoelectron from the current shell of the atom. This photoelectric absorption process leaves avacancy in the electron shell. It will immediately be filled by another electron, usually coming from an outer shell and thus less tightly bound, with a subsequent rearrangement of shell electrons. As energy will be liberated when a vacancy is filled, it may be emitted as electromagnetic radiation (a photon) or be transferred to an electron with less binding energy (Auger electron) which is ejected from the atom. The probability of having photons emitted is represented by the fluorescence yield. It can be found tabulated among spectroscopic data.

The emitted photons will have an energy representing the difference between the discrete energy levels of the shells involved. These emitted X-ray energies are characteristic of the involved element, enabling identification. Another element will have a different set of possible characteristic X-rays. If the vacancy is created in the K-shell, the emitted energies associated are denoted $K\alpha$ and $K\beta$. When characteristic X-rays like these are captured by a detector and the energies identified, it will reveal the presence of the element. The number of detected photons, or counts, is proportional to the concentration of the element in the measurement volume. [13]

(2-6) X-ray Fluorescence instrument:

There are some main benefits in favor for analysis of elements with a higher atomic number such as heavy metals, making them appropriate candidates for investigation.

The probability for a photoelectric process to occur is higher than for low atomic numbers, there is a higher fluorescent yield and the higher emitted energy is better at penetrating the surrounding tissue.

The XRF method is widely used to measure the elemental composition of materials. Since this method is fast and non-destructive to the sample, it is the method of choice for field applications and industrial production for control of materials.

X-ray Fluorescence (XRF) device which I used; is from Oxford instruments productions, this device named as X-strata-920, it works by exposing a sample to be measured to a beam of primary X-rays. The atoms of the sample absorb energy from the x-rays, become temporarily excited and then emit secondary x-rays.

Each element emits x-ray at a unique energy. By measuring the intensity and characteristic energy off the emitted X-rays; an XRF analyzer can provide qualitative and quantitative analysis regarding the thickness and composition of the material being tested.[14]

(2-7) The XRF spectrometer:-

Spectrometer systems are generally divided into two main groups Energy dispersive system (EDXRF) and wavelength dispersive systems (WDXRF). The difference between the two systems is found in the detection systems. EDXRF spectrometers have a detector the able to measure the different energies of the characteristic radiation coming directly from the sample. The detector can separate the radiation from the sample in to the radiation from the elements in the sample. This separation is called dispersion. WDXRF spectrometers use an analyzing crystal to dispersive the different energies. ALL radiation coming from the sample falls on the crystal. The crystal diffracts the different energies in the different directions.[2]

(2-8) XRF analysis:-

Qualitative analysis followed by Quantitative analysis. Qualitative Analysis determines which elements are present and their net intensities from the measured spectra.

Chapter 3

Chapter 3: work practical

(3-1) Introduction

In this work samples of cheese were analyses by using XRF technique to see the degree of their contamination with heavy to sic elements.

(3-2) Experimental Equipments

The equipment used in this experiment is one of the XRF spectrometers known as oxford instruments X-MET5000 (figure 1) is hand-held elemental analyzers intended for various different application. Example applications include; metal alloy analysis, soil and mining analysis, and electronic industry application. TheX-ME5000 series analyzes are based on energy dispersive X-ray fluorescence technology and uses an X-ray tube as source of excitation. The standard target material is Rhodium. The analyzer contains either a high resolution pinto-PIN diode

Detector with peltier cooling (X-MET5000) or silicon Drift Detector, SDD (X-MET5000).

The XMET provides a method for chemical analysis or sample identification (sorting) directly from samples in various forms. The instrument is fully portable analyzer with an integrated PDA (Personal Digital Assistant) computer. Within the X-MET analysis program, the user may select analytical modes, view spectra and save data.[20]

(3-3)Sample preparations

Samples of cheese were taken randomly five samplesfrom Khartoumwhitecheeseandfivesamplesofwhite cheeseDuwaimandfivesamples ofwhite cheesemade inKenanaand onesample of thecheesefactoryoutside Sudan.

(3-4) Experiments procedures

To find the concentration of heavy elements in the samples the following procedures are done:

1-the sample size are made equal 100 gram.

2-each sample is exposed to exiting source to be excited to emit their own characteristic photons .

3- The screen displayed directly the existing elements and their corresponding concentration.

(3-5) Results

The elements existing and their concentration in samples

Table(3.5.1):

The elements existing and their concentration in sample (1)

Element	Concentration%	STD
Cr	0.03	0.004
Mn	0.00	0.001
Fe	<0.02	0.003
Ni	0.01	0.001
Cu	0.00	0.001
Zn	0.00	0.001
Pb	0.00	0.00

Table (3.5.2)

The elements existing and their concentration in sample (2)

Element	Concentration%	STD
CR	0.02	0.004
Mn	0.00	0.002
Fe	<0.01	0.001
Ni	0.01	0.001
Cu	0.00	0.001
Zn	0.00	0.001
Pb	0.00	0.001

Table(3.5.3)

The elements existing and their concentration in sample (3)

Element	Concentration%	STD
CR	0.03	0.005
Mn	0.00	0.003
Fe	<0.01	0.003
Ni	0.01	0.001
Cu	0.00	0.001
Zn	0.00	0.001
Pb	0.00	0.001

Table(3.5.4)

The elements existing and their concentration in sample (4)

Element	Concentration%	STD
CR	0.02	0.002
Mn	0.00	0.002
Fe	<0.02	0.003
Ni	0.01	0.001
Cu	0.00	0.001
Zn	0.00	0.001
Pb	0.00	0.001

(3-6) Discussion:-

From the results by using x-ray fluorescence in all the samples of the cheese the concentration of heavy elements like pb, Cr and Zn are less than 0.04% and the highs concentration of all elements is chrom (cr) in all the samples and the less concentration of the elements are (cu,zn and pb) equals 0.001 and in one sample the concentration of pb equal zero

(3-7) Conclusion:-

Afteranexperimentand draw conclusionsusing X-ray spectraldevicefound that theconstituent elements ofcheesenormaland there is noany radioactiveelements in thecomponents of thecheese, as well as theconcentration ofthese elementsissuitableproportions.

(3-8) Recommendation:-

-Recommend a study in the same device to samples from dairy sources directly is that of determining the elements and focus and to compare these results to find out the difference and improvement of it.

- also recommended studying the same samples to determine the elements and focus to another device analyze and compare the results of the X-ray spectrometer and compared with the results of each of the two devices proportions standard and use the best hardware.

- Finally, I recommend using this device in Sudan, especially in the side of the safety of foods, especially manufactured.

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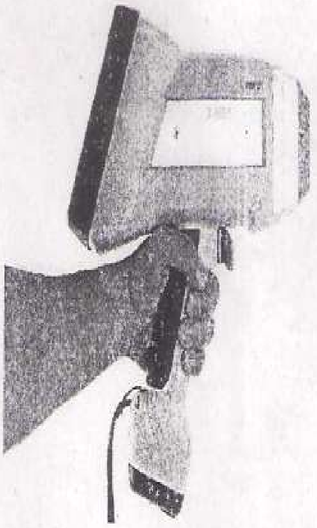


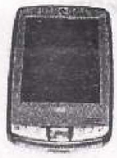
Figure 1

X-MET components

Principle parts


Analyzer


Battery (x2)


PDA computer

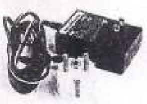

Stylus


Battery charger


Charger cable


Analyzer case

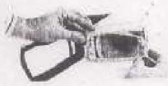
Included accessories


PDA AC multi-adaptor


PDA AC adaptor plug


Kapton window film kit


Reference cap


Rain cover

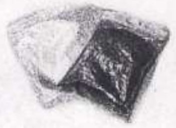
Continued; Included accessories

User's Manual (English)

Quick Start guide (12 languages)

Memory card reader

Optional accessories: Analyzer specific



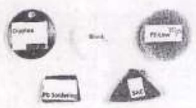
Sample bags

Sample cups

Background plate

Sample cup film

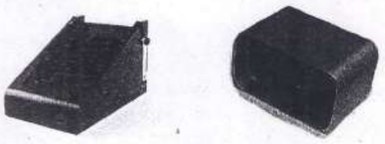
Sample pressing tool



Application specific Check samples

PDA-X-MET remoter connection cable

Benchtop stand



Light Travel stand : Includes small sample safety shield