Advances in the Performance and Application of Hemp Fiber

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***Abstract* — As a natural green textile raw materials, Hemp fiber research and applications has been increasingly wide spread. It has become an important raw material for textile fibers, it has excellent moisture absorption and release properties, air permeability, warmth retention, cold and warm sense, high temperature resistance, insulation, anti ultraviolet, anti radiation qualities, anti-mildew and antibacterial health-care properties and sound deadening properties. Hemp fiber has been widely used in many fields and products, such as clothing, sails, rope, paper and medical supplies. Recent advances in the performance and application of hemp fiber are investigated and discussed in this paper.**

Keywords - hemp; fiber; performance; application

I. INTRODUCTION

As early as the first century BC, cannabis has been a widely planted crop, the stagnation skin fiber served as one of the raw materials in the textile fiber, which can be used for the production of fiber products, clothing, sails, rope, paper and medical supplies. But in the traditional sense, hemp fiber has been considered to be a fiber can only be used in the manufacture of rope. Since the nineties of the twentieth century, along with the sharpening of the global environmental pollution, people's eyes turned to non polluting, antibacterial resource, which can be recycled for use and called "green resources." Under this situation, as the oldest of the textile crops, cannabis has been reentering in people's vision. At the same time, due to the continuous development of the textile technology, the fineness of hemp fiber continues to improve. It really digs out the use of marijuana comfort. Hemp fiber and its made of textiles have a series of excellent performance. Yin Xianggang, analyzed through the study of the status of hemp fiber, high temperature resistance, heat resistance and other properties [1]. Sun Xiaoyin and other key researchers explored the hemp fiber insulation, anti radiation and anti mildew antibacterial performance [2]. Li Yan studied through the comparison with hemp, flax, hemp fiber and its fabric; Li Dingtu discussed through analysis of hemp fiber temperature, thermal conductivity, permeability and other properties [3]. Hemp can be blended with cotton, wool and silk, and it can be spun. In addition to the above properties, hemp textile has antistatic property, unique style and fastness durable [4].

II. METHODOLOGY

A. *Brief Introduction to Hemp Fiber*

Hemp is one of the earliest textile fiber materials used by human beings [9]. Although some scholars believe that cannabis originated in Central Asia, but most scholars believe that cannabis originated in China, because in China people found a lot of cannabis cultivation resources. People began to plant and use cannabis. Historical records about 2800 BC, "Shennong" teach Chinese people to grow marijuana. Later Chinese history books recorded that hemp stem could be turned into fuel, hemp seed can be oil and processed into food, but early history books did not mention marijuana can be extracted from the drug.

In the 16th century, marijuana is widely cultivated in Europe. In addition to the acquisition of the fiber, people also cook the seeds and barley or other grains for eating. In 1953, Diseorides named it Cannabis (sativa), and considered it to be used in weaving ropes and refining drugs [5]. In 1545, Spaniards brought it to the Western Hemisphere, and began to grow it in Chile. 1645 hemp was introduced to the United States, England, the United States, the new, as a family of raw materials. Before the American Revolution, marijuana was introduced to Virginia and Pennsylvania [6]. In 1775, it was brought to Kentucky by the settlers from the state of Virginia, and grew well. When the eastern states give up planting marijuana, Kentucky's big industrial hemp has great development [7]. From the end of nineteenth Century to early twentieth Century, other states have tried to develop the cannabis industry. But since the end of the civil war, in 1912, virtually all of the cannabis products in the United States were produced in Kentucky [8]. In modern times, due to the hemp containing tetrahydro cannabinol (THC) was used to make doping and drug, which seriously harm the human

health and survival, so most of the western countries banned the cultivation of cannabis, cannabis use and research and thus also tends to a standstill.

Consumption weight of textile fibers increased in nearly 200 years, especially in the past 30 years. It has been a huge development. The total production and consumption of the textile fiber is from 1800000 tons in 1977 to 25000000 tons in 2007. Outlook 2050 due to the surge in demand for textile industry, consumption will continue to grow.

But the growth of textile fiber raw material is facing many difficulties. Due to the pressure of the global population on food demand, the cotton planting area in the future cannot be increased. The yield per unit area has little room for growth. Sheep wool production volume has been shrinking for 20 consecutive years. The world's total gross weight has been reduced from 3000000 tons in 1990 to 1200000 tons. The total amount of the fabric is 0.21%, which can not affect the overall situation.

Due to various limitations, it can only maintain the basic level of annual output of 2400000 tons. Regenerated cellulose fiber (including glue fiber, vinegar, etc.) needed to cool the fiber wood pulp. Cotton linter pulp has reached the limit, but it still needs to strive and open new sources. Synthetic fiber currently mainly relies on the oil and chemical raw materials. Therefore, the textile fiber material is faced with the need to go "renewable, biodegradable, recyclable, in accordance with the environmental requirements, in line with sustainable development and the development of biomass resources in harmony with other industries.

The cultivation of cannabis, low toxicity or non - toxic cannabis can be used to make use of land such as hills, slopes, salt, and tidal flats. At the same time, appropriate rotation can also reduce the crop of insects and disease the limited amount of fertilizer, the production cost is low. For the focus of the hemp fiber variety, the phloem used as a result of the porous structure and large specific surface area, the hemp stalk core can produce the wood powder and the manufacturing activity.

After entering the 1990s, with the increase of people's awareness of the level of "green" textile demand is increasing. Hemp fiber once again aroused people's attention. In particular, the 1992 low THC content of cannabis varieties in the United Kingdom foster success, so that the western countries have lifted the ban on marijuana, and began to focus on the application of hemp in the textile.

B. Performance of Hemp Fiber

Hemp fiber is one of the most delicate varieties of hemp fiber in Ramie fineness, which is equivalent with cotton fiber. The top of the hemp fiber is rounded, without the sharp tip of the blue and flax. Therefore, hemp textile is soft enough to avoid other bast fiber scratchiness and roughness without special treatment.

Hemp fiber is not only soft, but also has an elongated cavity and with the surface of the fiber longitudinal distribution of numerous cracks and small holes connected with excellent capillary effect, that makes the hemp fiber moisture wicking breathable performance good. The skin wear will feel comfortable soft talc. Taking cannabis canvas as an example, it is tested by national textile quality supervision and inspection center, the moisture absorption rate is reached, the bulk moisture efficiency is higher. According to estimates, wearing hemp clothing and cotton fabrics can make the body feel at a low temperature. Compared with the chemical fiber fabric it is cooler. In summer, even when the temperature reaches higher, wearing hemp clothing will not feel hot.

C. Classification of Cannabis

Cannabis is a kind of herbaceous crop, also known as hemp, true hemp, or common hemp [9]. From the perspective of Botany, there are many varieties of cannabis and genetic variation, which includes Cannabis Sativa, Cannabis Indica and Cannabis Ruderabis. Their structure, growth period, maturity and THC (four marijuana, marijuana in the spirit of Psychedelic elements) content are different. Cannabis Sativa is the most common type of marijuana, the highest can grow to 4 or 5 meters thick. It is the ideal material for paper and textile.

In the real life, the popular saying is basically according to the size of the cannabis toxicity (mainly three species THC, CBD and CBN) of the active ingredients of the cannabis are classified into cannabis (fiber-type hemp). Industrial hemp is used for industrial use. There are also drug cannabis (marijuana or Cannabis Indica) in India and intermediate type [6]. The content of the active ingredient is showed in Table I.

TABLE I CONTENTS OF ACTIVE CONSTITUENTS IN THE HEMP

	Medicinal type (toxic)	**Medium type**	**Fiber type**
THC (%)	>0.5	>0.4	<0.2
CBD (%)	<0.5	>0.5	>0.6
THC/CBD (%)	>1.1	>0.4	<0.1

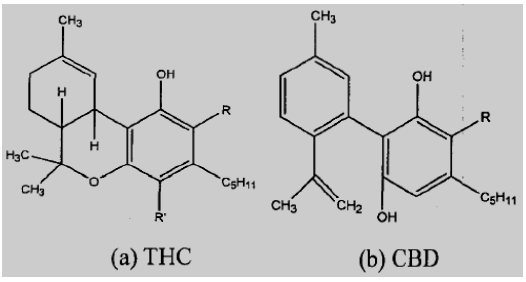


Figure 1. Chemical structure of THC, CBD and CBN

Chromosome of hemp fiber is: $2N = 20 = 4C/C + ZC/C + 12CT/CT + ZT/O$, Which belongs to a symmetrical karyotype. The chromosome number of prim (Cortex) and central column (Central Cylinder) is 40. Marijuana has large chromosome, the chromosome number of all kinds of hemp is the same. It is difficult to keep the pure breed. The chemical structure of THC, CBD and CBN are shown in figure 1. There is a marked difference in the characteristics of the product lines

or varieties, and the variety of production is difficult to establish.

D. Application of Hemp Fiber

1) Military applications

(1) Emergency product development

In 1970s, the Sino Vietnamese border war was still intoxicated. Due to the special geographical location, climate and humid, many officers and soldiers suffered from beriberi, tinea cruris and rotten crotch, so that the battle effectiveness of the army is greatly reduced. In the Central Military Commission of the high attention, after a large number of detailed investigations, hemp fiber with its unique properties is soon included in the development objects. Quartermaster research institutions timely research and produce with antibacterial deodorizing function socks, waist training shoes, underwear and other products in order to send to the front line. It can quickly solve the problem of officers and men of the illness.

(2) Special uniform development

The uniform type, drape, insulation, comfort, functional aspects need strict requirements. Dress, uniforms neat, training clothes need to be waterproof, windproof, insect resistant, sunscreen, antibacterial, strong wear resistance, anti infrared flame retardant, etc. Pilot clothing needs the resistance to load, and so on. Hemp fiber can meet all of these advantages.

(3) Special military product development

Using hemp core powder as raw material, a new generation of protective ability, light weight and high protection ability of the wood is made. Hemp seed protein extraction can be used for the production of high nutritional value of combat rations. Nowadays, the military diesel fuel is basically consistent, which can meet the requirements of the diversification of the army's energy.

2) Development of civil textiles

The rope with hemp is durable. The marijuana became popular in the world, especially in navigation. One of the world's first manufacturing ropes is one of the world's earliest cannabis growers in southern Russia. The first time they planted cannabis began in seventh Century BC. About 200 BC, the ancient Greek Hieron II introduced hemp from France to make use of cannabis to manufacture a boat with a rope. Because of the great contribution of the hemp rope to the sea, the cultivation and production of cannabis become more important.

3) Hemp fiber series products

(1) Knitted underwear

Underwear is a direct contact with the human skin clothing, known as the "human body second skin". Along with the improvement of living standards and the enhancement of health consciousness and environmental protection consciousness, people's demands on the underwear clothing are also increasing. Thus, people prefer underwear with good comfort, function and health care.

(2) T-shirt

Hemp fiber has the functions such as moisture permeability, good heat radiation, anti-static, anti ultraviolet, etc. Therefore, in the hot summer, wearing hemp clothing does not feel like to wear synthetic fabrics. It also won't feel like wearing cotton, silk and other natural ingredients clothing sweat sticky, but let a person feel cool thoroughly to caress your body. It will also prevent various diseases due to excessive ultraviolet radiation.

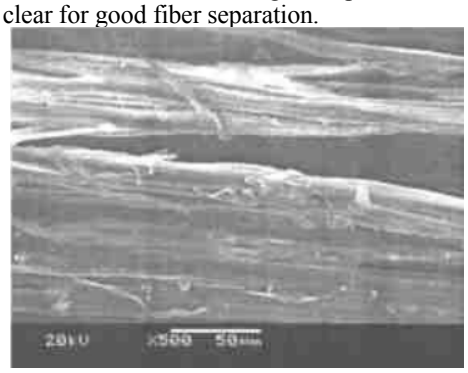
(3) Cowboy costume

The traditional denim uses cotton as the main raw material fabric. Adding hemp fiber can improve the denim quality, which makes the cowboy clothing have a wider adaptability and function. Marijuana cowboy clothing style is rough and comfortable. It overcomes the shortcomings of the pure cotton denim, poor ventilation, etc. It also has a rare health function.

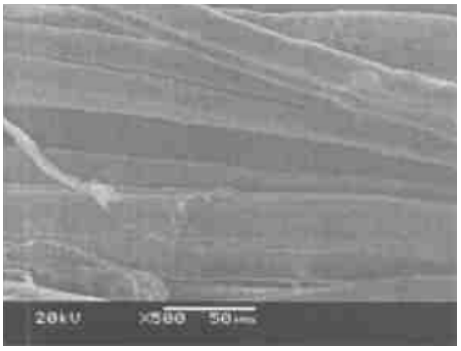
III. RESULTS AND DISCUSSION

A. Surface Observation of Hemp Fiber

Figure 2 is the electron microscope photo of the hemp fiber bundle before and after high temperature treatment. The original hemp fiber contains a lot of glial and other non cellulose material. Fiber surface is roughness, so that fiber are bonding together. There is a clear dense fiber bundle, fiber cluster. With NaOH in a high temperature the fiber bundle is clear for good fiber separation.



(a) The original Hemp



(b) NaOH, the Hemp with 120□ temperature

Figure 2. Hemp fiber bundle scanning electron microscope (× 500)

Figure 3 shows the SEM photos of the hemp fiber before and after high temperature treatment. It can be seen that the apparent diameter of hemp fiber is between 20 and 30μm, the surface of the hemp fiber is rough and uneven. And the surface of hemp fiber is very clear and smooth after high

temperature. It shows that most of the lignin and hemicellulose has been removed after high temperature, which increases the quality of the hemp fiber in the post process.

(a) The original Hemp

(b) NaOH, the Hemp with 120□ temperature

Figure 3.The hemp fiber scanning electron microscope

B. Performance Analysis of Hemp Fiber

Hemp fiber can be dissolved in hot concentrated alkaline solution. It is not affected in cold concentrated alkali, alkali, cold dilute inorganic acid. However it can be damaged in hot dilute acid and concentrated sulfuric acid. Mechanical physical properties of hemp fibers are shown in table II.

TABLE II PERFORMANCE COMPARE AMONG DIFFERENT KINDS OF HEMP

Hemp	Fiber Fitness (tex)	Breaking strength (cN/dtex)	Elongation rate (%)	Modulus of elasticity (cN/dtex)
Shandong Hemp	1.50	3.87	2.25	171.55
Jilin Hemp	3.05	2.46	2.38	94.98
Hebei Hemp	4.11	1.77	2.14	78.46
Single fiber of Ramie	0.63	6.74	3.77	
Hemp fiber	0.28	4.84	5.02	172.71

From table II we can find that hemp fiber fineness, high strength and single fiber breaking strength are better than flax below ramie in the process of flax spinning, but hemp fiber should be fine flax. Therefore, if the yarn fineness of hemp fiber needs to further increase, it will make hemp textiles become a strong competitor of flax textiles.

C. Application Analysis of Hemp Fiber

Hemp fiber still remains and has been absorbed by the trace amounts of cannabis, although it has been processed in the process of dyeing and finishing,. Scientific experiments and a large number of daily demands prove that: the cannabis phenolic within the hemp textiles has a significant effect of killing and inhibition substances on Staphylococcus aureus, Escherichia coli, Candida albicans. the test results are shown in table III.

TABLE III RESULTS OF ANTIBACTERIAL TEST OF HEMP FABRICS

Test items	Time	Hemp fabric
Staphylococcus aureus inhibition rate (%)	1h	92.36
	4h	97.37
Escherichia coli antimicrobial rate (%)	1h	92.38
	4h	97.56
Antibacterial rate of Candida albicans (%)	1h	92.26
	4h	96.66

Hemp textiles have high void rate. It has good sound absorption, permeability and good heat resistance, which can withstand the test of high temperature of 370℃. Therefore, in addition to the use of hemp clothing, hemp is also used for interior decoration. Hemp textile can be used as a decoration of the room. It can reduce the noise and give people working life to provide a quiet space. Because of its good moisture absorption, it can also adjust the indoor temperature and humidity, which is a natural green air conditioning.

IV. CONCLUSION

Hemp fiber itself belongs to cellulose fiber, which contains a large amount of polar hydrophilic groups. The moisture absorption of fiber is very good. Due to giant fibril longitudinal splitting, it shows many cracks and cavities. Thus, the capillary pipe and the cavity connected each other. According to this structure, hemp fiber has excellent moisture absorption and air permeability performance, is unmatched by other textiles. So hemp fiber moisture absorption, wetting, drying and cooling performance are really good.

Hemp fiber has unique properties, textile products fast durable, comfortable, breathable moisture wicking cool. The organizational structure and yarn structure have a great relationship. At present, the important problem in the artificial blood vessel in China is that the resistance of the fabric is poor. Although the thickness of the fabric can be achieved by various means, the permeability is still an important aspect of the future research.

The knitted vascular grafts have a porous structure, which makes it compatible with the new tissue. But it may also lead to the post transplant blood from the gap to penetrate out. In order to reduce the risk of bleeding, people use a knitted graft inside and outside surface of napping to fill those gaps. Another method is in the process of transplanting, with seal of a patient's blood or pre congestion

graft, but it took a long time. Its effectiveness depends on the patient's blood chemical properties and the surgeon's skills.

The structure of product is smaller than woven knitted products, which can reduce the pore, the leakage of blood from the slot, but it will also hinder the growth of the organization. The typical water penetration rate of woven fabric is 50 ~ 500mL/cm2.min, and the knitted fabric is 1000 ~ 2000 mL/cm2.min. In order to fill the void to prevent leakage, people developed in the pile surface brushed products, woven or knitted vascular prostheses. Vast most artificial blood vessel is prior to transplantation in first after the pre coagulation, namely conscious will wall blood impregnated to textile materials, the formation of blood clots, once transplanted, presetting measures make the textile material tube wall passage of blood to reduce or even eliminate.

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ANNEX (Table III)

Report: HONGJIE ZHANG et al: ADAVANCES IN THE PERFORMANCE AND APPLICATION OF HEMP FIBER (2011), Table III

Recieved from the author in connection with an interview in Beijing, by PhD, Ing, Anders Thygesen, DTU in September 2017. Translated from Chinese.

2.2 Experimental method

2.2.1 Sample preparation
The hemp fiber samples 1, 2 and the hemp fiber ultrafine powder samples 1 and 2 were sterilized

2.2.2 Preparation of culture medium
(1) Preparation of nutrient agar medium
2.5g of sodium bicarbonate, 2.5ml of distilled water, 500ml of distilled water, stir with a glass rod, so that the components as far as possible evenly dissolved in distilled water, and then with 0.1mol / LNaOH and HCl to adjust the pH of the culture medium to about 6.8, add nutritious agar powder 9g, continue to heat up until the nutrient agar powder is completely dissolved, and then nutrient agar medium in a conical flask, into the high pressure steam sterilizer In the 121 °C conditions for 20 minutes sterilization, as a backup.

(2) broth culture medium preparation
5 g of peptone, 2.5 g of beef extract and 2.5 g of sodium chloride were poured into a beaker and then 500 ml of distilled water was added. The pH of the medium was adjusted to neutral with 0.1 mol / L NaOH and HCl. All the ingredients were dissolved, and the broth culture medium was then dispensed into a conical flask, sealed and sterilized at 121 ° C for 20 min.

(3) Preparation of 0.03 M PBS buffer
First, mix 72 ml of Na2HPO4 solution and 28 ml of Na2H2PO4 solution, then add 5g of NaCl particles, and finally add 1000ml of distilled water to dilute the bottle thoroughly dispersed material, and then 0.1mol / LNaOH and HCl solution will buffer The pH of the liquid was adjusted to 7.0, and then the Erlenmeyer flask was charged with 100 ml of buffer and sealed. And finally sterilized in an autoclave at 121 ° C for use.

(5) sterilization
The culture dish in accordance with the dry sterilization method, with a bottom cover to form a set, with the newspaper to be used in the laboratory to pack, put in the electric blast oven, and then the temperature modulation to 150 °C 2h sterilization treatment, spare.

Wet sterilization
A 100 ml 0.02 ml PBS buffer solution packed with a Erlenmeyer flask was sealed and a tube containing 9 ml of 85% saline was sealed. The tubes were bundled and used for ease of use and finally placed in a high temperature sterilization pot at 121 °

C Sterilization under 20min, spare

2.2.3 culture of bacteria

The preserved strains were inoculated into a conical flask containing broth culture medium at 37 ± 1 ° C and 120 rpm for 6 to 8 hours, followed by turbidimetry, And then use a series of dilution of broth prepared into inoculation suspension, to ensure that 1ml bacteria containing viable cells should reach 1 × 106-107cfu / mL.

2.2.4 Antimicrobial Experiments

(1) Sample inoculation

Standing 15min prepared bacteria solution, with a pipette to remove 1ml of bacteria, were added to the sample of the Erlenmeyer flask, cover the bottle, shake about a few times, so that the bacteria is fully absorbed by the sample.

(2) in the "0" contact time to prepare bacteria

After inoculation, add 100 ml of 0.02 PBS PBS buffer to the flask containing the sample, shake the flask vigorously for 3 min, wash the bacteria on the sample, remove the 1 ml fluid from the pipette, (The pipette tip can not be in contact with the saline in the tube), the tube tube shake the tube solution mixed evenly, the bacteria liquid made 1:10 dilution. Dilute the bacteria solution in the above dilution order, and dilute it once every time, and use one sterile straw. Until the bacteria solution to achieve the required dilution factor, and then remove the 1ml dilution into the sterilization plate, the prepared sterilized nutrient agar quickly into the rotation plate to make the bacteria and nutrient agar mixed evenly, the whole operation Sterile console. Nutrient agar after solidification, the plate turned over to prevent water droplets dripping onto the medium, affecting the test results, the inverted plate into the incubator incubated 48 ± 2h after the removal (incubator temperature maintained at 37 ± 1 ° C), accurately calculate the number of colonies in the plate, multiplied by the corresponding dilution factor, the result is the number of colonies in the sample.

Selection of dilution factor:

The average number of colonies in the culture dish is generally chosen to be between 30 and 300, and then multiplied by the corresponding dilution factor, resulting in the total number of bacteria. If there are two dilutions, and meet the average number of colonies in the range of 30 to 300 between the conditions, with a larger value divided by a smaller value of the colony value, if the result is less than 2, take the average; Greater than 2, whichever is smaller; if the average number of colonies in all dilutions exceeds 300, the total number of colonies in terms of the maximum number of colonies and the dilution factor is the total number of bacteria; if the average number of colonies in all dilutions is 30 The total number of bacteria and the dilution factor of the lowest dilution are taken as the total number of bacteria; if all dilutions have no colonies, the total number of bacteria is obtained by multiplying by less than 1 by the lowest dilution factor. If the average number of colonies in all dilutions is not in the range of 30 to 300, the average number of colonies with the average number of colonies closest to the average number of colonies can be obtained by multiplying the total number of colonies and the total number of bacterial colonies within 100 , When the total number of colony is greater than 100, the

application of two effective digital calculation, in order to facilitate the convenience of statistics, the actual experiment is often used to express the index of 10.

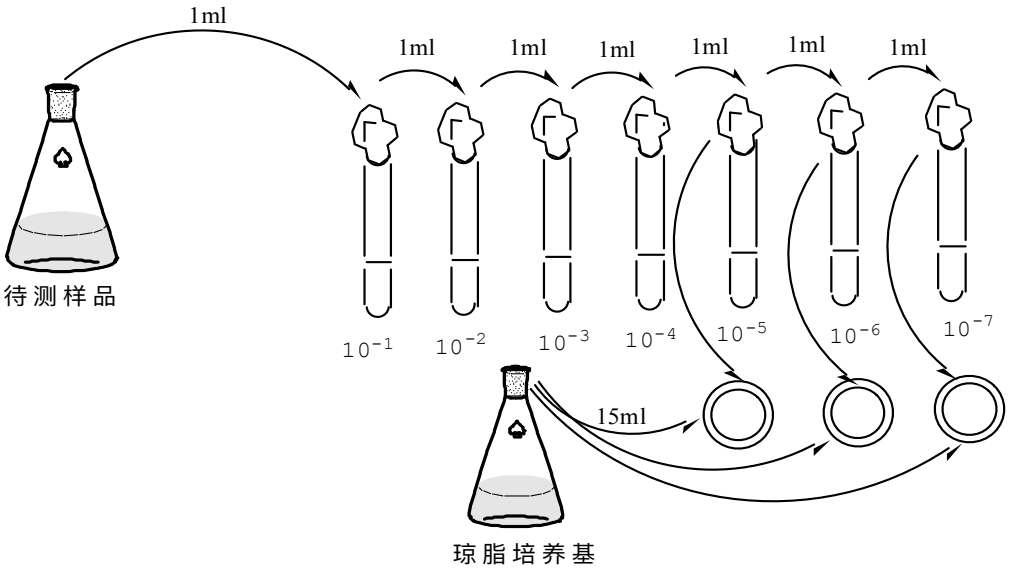

Figure 2-1 Schematic diagram of antimicrobial experiments

(3) regular culture after the preparation of bacteria samples

The Erlenmeyer flask, which had the same sample, was incubated in a 37 ± 1 incubator for 20 ± 2 hours. After removal,

(4) colony counting method

The total number of bacterial colonies is equal to the number of colonies and dilution multiple of each dish. When calculating the number of colonies in the culture dish, it is generally observed by the naked eye. For the colony is too small, it is difficult to observe. Affect the correctness of the next step.

In the experiment, the average number of colonies in the range of 30 to 300 was selected as the standard for colony determination. Each dilution should ensure that at least 2-3 plates are used and that the average of the number of colonies in the same dilution petri dish should be used as the number of colonies of the sample. For large flaky colonies, the culture dish can not be used, should be selected without flaky colonies growth, colonies evenly distributed culture dish; if the culture plate appears in the distribution of flaky colony is less than 1 / 2, and the other parts of the Petri dish are evenly distributed and the number of colonies representing the whole culture dish can be multiplied by two half dishes.

2.2.5. Calculation of bacteriostatic rate

$$\beta(\%) = \frac{B - A}{B} \times 100\%$$

β: inhibitory rate;

B: "0" exposure to control bacteria;

A: The number of bacteria cultured for 24 hours