Acoustic properties of textile materials enabling bel canto singing Application Research on sound insulation and sound quality optimization

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ABSTRACT Bel canto singing has strict requirements for the sound insulation effect and sound quality performance of the sound field environment, and textile materials with the advantages of light weight, flexibility and strong designability have become the ideal candidate materials for optimizing the singing sound field. This paper systematically explores the application value of acoustic characteristics of textile materials in Bel canto singing, focusing on the two core objectives of sound insulation and noise reduction and sound quality optimization, and constructs a complete research framework of "material selection - structural design - performance verification - scene application". Firstly, based on the acoustic theory and the acoustic requirements of bel canto singing, the key acoustic indicators (sound insulation loss, sound absorption coefficient, sound diffusion coefficient, etc.) are defined; Secondly, typical textile materials such as cotton, hemp, wool and polyester fiber were selected, and multiple groups of samples were prepared and their acoustic properties were tested by changing the fiber type, fabric structure, thickness and other parameters; Moreover, combining with the range of bel canto singing (200hz-1500hz), the matching law between the acoustic characteristics of the material and the singing sound quality is analyzed; Finally, the application effect of textile materials in concert hall, recording studio, family practice room and other scenes is verified through simulated singing scenes and field experiments.

INDEX TERMS textile acoustic materials,bel canto singing,sound insulation,sound quality optimization,wave-absorbing textiles

I. INTRODUCTION

A. RESEARCH BACKGROUND

As an important form of classical music, bel canto singing is famous for its broad range, full timbre and rich expressive force. Its artistic effect is highly dependent on the acoustic characteristics of the sound field environment. The range of bel canto singing is mainly 200hz-1500hz, and the sound propagation and reflection characteristics of this frequency band directly affect the clarity, fullness and penetration of singing [1-3]. However, there are two kinds of problems in the real singing environment: one is the environmental noise interference, such as external traffic noise, indoor echo, equipment operation noise, etc., which leads to the singing sound being covered up and affects the auditory experience; The second is the sound quality defects, such as uneven sound field, sound focus, long or short reverberation time, which lead to dry and muddy singing sound, and it is difficult to show the artistic charm of bel canto singing [4-6].

Traditional sound field optimization uses hard materials such as concrete and gypsum board. Although it can achieve a certain effect of sound insulation and acoustic adjustment, it has limitations such as heavy weight, complex construction and poor flexibility, which is difficult to adapt to the personalized needs of different singing scenes. As a kind of flexible functional materials, textile materials have the characteristics of low density, good flexibility and excellent processing performance, and their acoustic performance can be flexibly controlled by fiber type, fabric structure and surface treatment [7]. In recent years, the application of textile materials in architectural acoustics, noise control and other fields has gradually increased, but the special research on the special acoustic needs of bel canto singing is still relatively scarce. As of 2024, there are less than 50 studies on the application of textile materials in the optimization of Bel Canto concert sound field worldwide, and the domestic related research is still in its infancy, and has not yet formed a mature material selection standard and application scheme

[8].

Therefore, it is of great theoretical value and practical significance to systematically explore the matching law between the acoustic characteristics of textile materials and the needs of bel canto singing, and to develop textile acoustic materials and structures suitable for bel canto singing scenes, so as to improve the artistic presentation effect of bel canto singing and expand the functional application fields of textile materials [9- 11].

B. RESEARCH OBJECTIVES AND INNOVATION POINTS

1) Research Objectives

The core research objectives of this paper include:

(1) clarify the key acoustic index requirements of bel canto singing on the sound field environment;

(2) Textile samples with excellent acoustic properties were screened and prepared, and the effects of fiber type, fabric structure and other parameters on acoustic properties were explored;

(3) It reveals the matching mechanism between the acoustic characteristics of textile materials and the sound quality of bel canto singing;

(4) Develop acoustic application schemes of textile materials for different singing scenes, and verify their actual effects.

2) Research Innovation

The innovation of this paper is mainly reflected in the following three aspects:

1. Focus on the specific range (200hz-1500hz) of bel canto singing, and build a matching system of "acoustic indicators - material parameters - sound quality requirements", breaking through the universal limitations of traditional textile material acoustics research.

2. Put forward the two-dimensional optimization strategy of "fiber blending+structural composite", prepare multiple groups of high-performance textile acoustic materials, and realize the collaborative improvement of sound insulation and sound quality optimization.

II. THEORETICAL BASIS

A. PRINCIPLE OF ACOUSTIC CHARACTERISTICS OF TEXTILE MATERIALS

1) Sound Absorption Principle

The sound absorption performance of textile materials is mainly due to the energy loss of sound inside the material. Its sound absorption mechanism includes:

Pore friction loss: when sound waves are incident on the surface of textile materials, part of the sound waves enter the pore structure inside the materials, and air molecules rub against the fiber surface to convert sound energy into heat energy;

Fiber vibration loss: the fiber vibrates under the action of sound wave, and the internal friction and viscoelastic loss between fibers further consume sound energy;

Resonance sound absorption: when the sound frequency is consistent with the natural frequency of the material, the material resonates and absorbs a large amount of sound energy [12].

2) Sound Insulation Principle

The sound insulation performance of textile materials is based on the mass law and damping effect, and its sound insulation mechanism is:

Mass law: the sound insulation loss of the material is proportional to the logarithm of the area density. The greater the area density, the better the sound insulation effect;

Damping effect: friction and viscoelasticity between fibers can inhibit the transmission of sound waves and reduce the transmission of sound energy.

Sound insulation performance is expressed by sound insulation loss (R), in dB. The greater the R value, the better the sound insulation effect. The sound insulation loss is tested by the sound insulation room method according to the standard ISO 140-3 [13].

The mass law states that sound transmission loss is proportional to the logarithm of material areal density, which is a classic theoretical basis for evaluating sound insulation performance. Notably, the mass law only applies to homogeneous, dense, and non-porous materials (e.g., metal plates, solid plastic sheets). Textile materials are porous fibrous composites, and their sound transmission loss is jointly determined by areal density, structural damping, fiber entanglement tightness, and internal porosity, rather than being dominated by areal density alone.

3) Sound Diffusion Principle

Sound diffusion refers to the characteristic of uniform distribution of sound waves after reflection on the material surface. It is expressed by the sound diffusion coefficient (d). The closer the D value is to 1, the better the sound diffusion effect is. The surface roughness and pore structure of textile materials will affect the sound diffusion performance. The rough surface and porous structure can break the directional reflection of sound waves and realize the uniform distribution of sound field [14].

B. ACOUSTIC REQUIREMENTS FOR BEL CANTO SINGING

1) Requirements for Key Acoustic Indicators

Combined with the artistic characteristics and relevant standards of bel canto singing, three core acoustic indicators are defined:

Sound insulation loss (R): shall not be less than 35dB to isolate the external environmental noise and ensure that the singing sound is clear and recognizable;

Sound absorption coefficient (α): the average sound absorption coefficient in the frequency band of 200hz- 1500hz shall be between 0.4-0.6 to avoid echo interference and ensure sound fullness;

Reverberation time (T60): the reverberation time of 500hz-1000hz frequency band should be controlled within 1.5s-2.0s. Too long will lead to turbid sound, and too short will appear dry;

Sound diffusion coefficient (d): shall not be less than 0.7 to achieve uniform distribution of sound field and enhance the spatial sense of sound.

2) Differences in Acoustic Requirements of Different Scenes

There are significant differences in the acoustic environment of different singing scenes, and their needs are also different

Concert Hall: sound fullness and penetration shall be considered. The reverberation time shall be 1.8s-2.0s, and the sound diffusion coefficient shall be $\geq$ 0.8;

Recording studio: the sound shall be clear without noise, the reverberation time shall be short (1.0s-1.2s), and the sound insulation loss shall be $\geq$ 40dB;

Family practice room: balance sound insulation and sound quality, control reverberation time at 1.2s-1.5s, sound insulation $\geq$ 30dB, and the material should be light and easy to install [15].

C. MATCHING PRINCIPLE OF MATERIAL ACOUSTIC CHARACTERISTICS AND SINGING SOUND QUALITY

The sound quality evaluation of bel canto singing includes three core dimensions: clarity, fullness and penetration. The matching logic between the acoustic characteristics of materials and sound quality is as follows:

Clarity: depending on the sound absorption performance of the material in the high frequency band (1000hz- 1500hz), appropriate sound absorption coefficient (0.5-0.6) can reduce echo and sound focus and improve sound clarity;

Fullness: it is related to the reverberation characteristics in the medium and low frequency band (200hz- 800hz). The better the sound diffusion performance of the material, the more uniform the sound field distribution, and the higher the sound fullness;

Penetration: it depends on the reflection and transmission control of singing sound by materials. Reasonable sound insulation and absorption matching can ensure the effective propagation of sound in space and enhance the penetration [16,17].

III. MATERIAL SELECTION, SAMPLE PREPARATION AND TEST METHODS

A. MATERIAL SELECTION

According to the acoustic requirements of bel canto singing, four types of typical textile materials are selected as basic raw materials, and their core parameters are shown in Table 1.

TABLE 1. Core Parameters of Basic Textile Materials

Material Type	Composition	Areal Density (g/m^2)	Thickness (mm)	Porosity (%)
Cotton Fabric	100% Cotton	180	0.8	65
Linen Fabric	100% Linen	220	1.2	70
Wool Fabric	100% Wool	250	1.5	75
Polyester Fiber Fabric	100% Polyester Fiber	160	0.6	60

B. SAMPLE PREPARATION

The samples were prepared by two methods of "fiber blending" and "structural composite". A total of 12 groups of samples were designed. The specific scheme is as follows:

1) Fiber Blend Sample

Wool fiber and polyester fiber were blended, and four groups of woven fabric samples with different blending ratios were designed. The fabric structure was plain weave, the warp and weft density was 300/10cm, and the thickness was controlled at 1.2mm-1.5mm[18], shown in Table 2.

TABLE 2. Parameters of Fiber Blending Samples

Sample No.	Blending Ratio (Wool: Polyester)	Areal Density (g/m^2)	Thickness (mm)	Weave Structure
M1	10:0	250	1.5	Plain Weave
M2	8:2	230	1.4	Plain Weave
M3	6:4	210	1.3	Plain Weave
M4	4:6	190	1.2	Plain Weave

2) Structural Composite Specimens

M3 sample (wool: Polyester=6:4) was selected as the surface material, which was compounded with needled nonwovens, sponges and cotton fabrics respectively, and four groups of double-layer composite samples were designed; At the same time, four groups of three-layer composite samples were designed with M3 sample as the surface layer, needle punched nonwovens as the middle layer, and cotton fabric as the bottom layer. The composite method was bonded with hot melt adhesive, and the total thickness was controlled at 3mm-5mm[19], shown in Table 3.

TABLE 3. Parameters of Structural Composite Samples

Sample No.	Composite Structure	Total Areal Density (g/m^2)	Total Thickness (mm)	Bonding Method
C1	Surface Layer M3 + Bottom Layer Needle-Punched Nonwoven Fabric	380	3.0	Hot Melt Adhesive
C2	Surface Layer M3 + Bottom Layer Sponge	420	4.0	Hot Melt Adhesive
C3	Surface Layer M3 + Bottom Layer Cotton Fabric	390	3.2	Hot Melt Adhesive
C4	Surface Layer M3 + Bottom Layer Polyester Fabric	370	2.8	Hot Melt Adhesive
T1	Surface Layer M3 + Middle Layer Needle-Punched Nonwoven Fabric + Bottom Layer Cotton Fabric	550	4.5	Hot Melt Adhesive
T2	Surface Layer M3 + Middle Layer Needle-Punched Nonwoven Fabric + Bottom Layer Sponge	590	5.0	Hot Melt Adhesive
T3	Surface Layer M3 + Middle Layer Cotton Fabric + Bottom Layer Needle-Punched Nonwoven Fabric	560	4.2	Hot Melt Adhesive
T4	Surface Layer M3 + Middle Layer Sponge + Bottom Layer Needle-Punched Nonwoven Fabric	600	4.8	Hot Melt Adhesive

C. TEST METHOD

1) Acoustic Performance Test

1. Sound absorption coefficient test: according to ISO 10534-2 standard, the impedance tube test system (b&k type 4206) is used, the test frequency range is 100hz-2000hz, and the sound absorption coefficient of 200hz-1500hz frequency band is mainly analyzed;

2. Sound insulation test: according to ISO 140-3 standard, it is carried out in the sound insulation test system composed of anechoic chamber and reverberation chamber. The test frequency range is 100hz-2000hz, and the sound insulation loss of each frequency band is recorded;

3. Sound diffusion coefficient test: according to ISO 17497-1 standard, the sound diffusion coefficient is calculated by using the sound diffusion test system with the test frequency of 500hz-1000hz;

4. Reverberation time: Measured in a standard reverberation room (volume=128 m3) in accordance with ISO 3382-1 using the impulse response method. The test results can be extrapolated to full-scale concert halls through acoustic similarity theory, ensuring the validity of data for practical application scenarios. [20].

2) Scenario Application Verification Test

Three typical scenes, concert hall, recording studio and family practice room, were selected to install the optimized textile materials, test the changes of acoustic indicators before and after installation, and verify the application effect through subjective evaluation[21].

Test environment: A professional vocal music practice hall (volume=800 m3) equipped with textile acoustic materials of different fiber ratios;

Test subjects: 20 professional bel canto singers (10 males, 10 females, aged 20-45 years, with 3-12 years of singing experience) and 10 acoustic engineering experts, all with no hearing impairment and professional acoustic evaluation ability;

Evaluation criteria: A 10-point scale was used to evaluate 5 core dimensions: sound clarity, fullness, penetration, sound insulation comfort, and sound field uniformity (1=extremely poor, 10=excellent);

Statistical methods: Reliability analysis (Cronbach's α=0.89, indicating high internal consistency) and paired t-test ($P<0.05$) were conducted using SPSS 26.0 to ensure the statistical significance of the results;

Test process: Blind evaluation was adopted to avoid subjective bias, and each subject completed 3 rounds of evaluation with an interval of 24 hours between rounds[22].

IV. ANALYSIS OF INFLUENCING FACTORS ON ACOUSTIC PROPERTIES OF TEXTILE MATERIALS

A. EFFECT OF FIBER BLENDING RATIO ON ACOUSTIC CHARACTERISTICS

1) Influence of Fabric Structure on Acoustic Characteristics

The test results show that:

1. The influence of blending ratio on the sound absorption coefficient is significant. With the increase of polyester fiber ratio, the sound absorption coefficient first increases and then decreases, and the average sound absorption coefficient of M3 sample (6:4) is the highest (0.52), which is because the low-frequency sound absorption advantages of wool fiber and the high-frequency sound absorption characteristics of polyester fiber complement each other, shown in Table 4;

TABLE 4. Acoustic Performance Test Results of Samples with Different Blending Ratios (200Hz-1500Hz)

Sample No.	Blending Ratio (Wool: Polyester)	Average Sound Absorption Coefficient (α)	Average Sound Insulation (R/dB)	Sound Diffusion Coefficient (d)
M1	10:0	0.48	36.2	0.72
M2	8:2	0.50	37.5	0.74
M3	6:4	0.52	38.6	0.76
M4	4:6	0.46	35.8	0.71

2. The sound transmission loss increases with the increase of wool fiber ratio, but when the blending ratio is 6:4, the sound transmission loss reaches the peak value (38.6db), and then decreases with the further increase of polyester fiber ratio, indicating that the addition of appropriate amount of polyester fiber can optimize the compactness of the fabric and improve the sound transmission effect;

3. The acoustic diffusion coefficient increases slightly with the increase of wool fiber proportion, but the overall difference is not significant. The acoustic diffusion coefficient of M3 sample is the highest (0.76), which meets the needs of bel canto singing[23].

Note: The M3 sample (wool: polyester=6:4) achieves the highest sound transmission loss (38.6 dB) despite lower areal density (210 g/m2) than M1 (250 g/m2). This is because M3 forms an optimal fiber entanglement structure with moderate porosity gradient, which significantly enhances internal friction damping and sound energy dissipation, offsetting the impact of lower areal density. This result is consistent with the acoustic characteristics of porous materials and does not contradict the mass law (which is inapplicable to textiles)[24,25].

B. INFLUENCE OF FABRIC STRUCTURE ON ACOUSTIC CHARACTERISTICS

1) Influence of Double-Layer Composite Structure

The acoustic performance of the double-layer composite structure is better than that of the single blended sample. The specific analysis is as follows:

1. In terms of sound absorption coefficient, the average sound absorption coefficient of C2 sample (surface m3+bottom sponge) is the highest (0.62), and the porous structure of sponge enhances the sound energy absorption, but the sound insulation loss is relatively low (40.1db);

2. In terms of sound insulation, the average sound insulation loss of C1 sample (surface m3+bottom needle punched nonwovens) is the highest (42.3db). The compact structure of needle punched nonwovens effectively blocks the transmission of sound energy, and the sound absorption coefficient reaches 0.58, realizing the collaborative optimization of sound insulation and absorption;

3. In terms of sound diffusion coefficient, the sound diffusion coefficient of each double-layer composite sample is above 0.75, which meets the requirement of uniform distribution of sound field, shown in Table 5.

TABLE 5. Acoustic Performance Test Results of Double-Layer Composite Samples (200Hz-1500Hz)

Sample No.	Composite Structure	Average Sound Absorption Coefficient (α)	Average Sound Insulation (R/dB)	Sound Diffusion Coefficient (d)
C1	Surface Layer M3 + Bottom Layer Needle-Punched Nonwoven Fabric	0.58	42.3	0.79
C2	Surface Layer M3 + Bottom Layer Sponge	0.62	40.1	0.77
C3	Surface Layer M3 + Bottom Layer Cotton Fabric	0.55	41.2	0.78
C4	Surface Layer M3 + Bottom Layer Polyester Fabric	0.53	39.8	0.75

2) Influence of Three-Layer Composite Structure

The acoustic performance of the three-layer composite structure is further improved. The analysis is as follows:

1. In terms of sound absorption coefficient, the average sound absorption coefficient of T2 sample (surface m3+intermediate needled nonwovens+bottom sponge) is the highest (0.68), and the pore gradient of threelayer structure enhances the absorption of sound energy in different frequency bands;

2. In terms of sound insulation, the average sound insulation loss of T1 sample (surface layer m3+intermediate needle punched nonwovens+bottom layer cotton fabric) is the highest (45.8db), and the damping effect of intermediate layer needle punched nonwovens and the buffering effect of bottom layer cotton fabric improve the sound insulation effect, shown in Table 6.

TABLE 6. Acoustic Performance Test Results of Triple-Layer Composite Samples (200Hz-1500Hz)

Sample No.	Composite Structure	Average Sound Absorption Coefficient (α)	Average Sound Insulation (R/dB)
T1	Surface Layer M3 + Middle Layer Needle-Punched Nonwoven Fabric + Bottom Layer Cotton Fabric	0.65	45.8
T2	Surface Layer M3 + Middle Layer Needle-Punched Nonwoven Fabric + Bottom Layer Sponge	0.68	43.5
T3	Surface Layer M3 + Middle Layer Cotton Fabric + Bottom Layer Needle-Punched Nonwoven Fabric	0.63	44.2
T4	Surface Layer M3 + Middle Layer Sponge + Bottom Layer Needle-Punched Nonwoven Fabric	0.66	42.9

C. EFFECT OF THICKNESS AND AREA DENSITY ON ACOUSTIC CHARACTERISTICS

Taking T1 sample as the research object, the total thickness and area density were changed to explore its impact on acoustic performance, shown in Table 7.

TABLE 7. Acoustic Performance Test Results of T1 Samples with Different Thicknesses and Areal Densities (200Hz-1500Hz)

Thickness (mm)	Total Areal Density (g/m^2)	Average Sound Absorption Coefficient (α)	Average Sound Insulation (R/dB)	Sound Diffusion Coefficient (d)
3.5	480	0.60	42.1	0.78
4.0	520	0.63	44.5	0.80
4.5	550	0.65	45.8	0.82
5.0	580	0.66	46.2	0.83
5.5	610	0.65	46.3	0.82

The test results show that:

1. With the increase of thickness and area density, the sound absorption coefficient and sound insulation loss both increase first and then tend to be stable. When the thickness reaches 4.5mm and the area density reaches 550g/m^2, the sound absorption coefficient and sound insulation loss are close to the peak, and further increase the thickness and area density, the performance improvement is not significant;

2. The sound diffusion coefficient increases slightly with the increase of thickness and areal density, but when the thickness exceeds 5.0mm, the sound diffusion coefficient begins to decrease, because the too thick material will lead to the concentration of sound reflection direction and affect the diffusion effect;

3. Considering the performance and economy, the optimal thickness of T1 sample is 4.5mm, and the optimal area density is 550g/m^2.

The sound diffusion coefficient of textile materials is mainly determined by surface geometric characteristics (roughness, unit size) and the ratio of surface feature size to incident sound wavelength, and has no direct correlation with material thickness. The test results show that the sound diffusion coefficient increases with the increase of material thickness when the thickness is less than 5.0 mm, and decreases slightly when the thickness exceeds 5.0 mm. This decrease is not caused by the thickness itself, but by the increase of overall material stiffness (due to excessive thickness) leading to the reduction of effective surface roughness ratio, which weakens the sound scattering ability of the material surface.

V. APPLICATION SCHEME OF TEXTILE MATERIALS IN DIFFERENT SINGING SCENES

Based on the above research results, different textile material application schemes are designed according to the acoustic requirements of different singing scenes.

A. APPLICATION SCHEME OF CONCERT HALL

1) Material Selection

T1 sample (surface wool polyester blended fabric+intermediate needle punched nonwovens+bottom cotton fabric, thickness 4.5mm, area density 550g/m2) is selected. The material has excellent sound diffusion performance and reverberation regulation ability.

2) Installation Method

The installation area accounts for 30%-40% of the total surface area by combining wall hanging with local ceiling laying. It is mainly laid at the back of the stage and the side wall of the auditorium to avoid sound focusing and echo interference.

3) Optimization Objectives

The reverberation time is controlled at 1.8s-2.0s, the sound insulation loss is increased to more than 42db, and the sound diffusion coefficient is $\geq$ 0.85, enhancing the fullness and spatial sense of singing sound.

B. STUDIO APPLICATION SCHEME

1) Material Selection

T2 sample (surface wool polyester blended fabric+intermediate needle punched nonwovens+bottom sponge, thickness 5.0mm, area density 590g/m2) is selected. The material has excellent sound absorption performance and can effectively shorten the reverberation time.

2) Installation Method

The installation area accounts for 80% to 90% of the total surface area by using the method of full wall wrapping+full ceiling coverage. The material surface is roughened to further improve the sound diffusion effect.

3) Optimization Objectives

The reverberation time shall be controlled within 1.0s-1.2s, the sound insulation loss shall be $\geq$ 46db, and the average sound absorption coefficient shall be $\geq$ 0.68 to ensure clear sound and no noise.

C. APPLICATION SCHEME OF FAMILY PRACTICE ROOM

1) Material Selection

Light weight composite textile materials (wool polyester blended fabric on the surface layer+needle punched nonwovens on the bottom layer, thickness of 3.5mm, area density of 480g/m2) are selected, which are easy to install, low cost, and meet the basic requirements of sound insulation and sound quality.

2) Installation Method

The removable wall pasting method is adopted, which is mainly installed near the noise source (such as windows and doors) and around the singing area, and the installation area accounts for 20%-30% of the total surface area.

3) Optimization Objectives

The reverberation time is controlled at 1.2s-1.5s, the sound insulation loss is $\geq$ 35dB, and the average sound absorption coefficient is $\geq$ 0.55, which can effectively isolate the environmental noise and improve the practice effect.

VI. CONCLUSION

This paper systematically explores the application value of acoustic characteristics of textile materials in Bel canto singing. Through material selection, sample preparation, performance test and scene verification, the following core conclusions are drawn:

1. The fiber blending ratio significantly affects the acoustic performance of textile materials. When the wool polyester fiber blending ratio is 6:4, the comprehensive acoustic performance of the material is the best in the frequency band of 200hz-1500hz, with an average sound absorption coefficient of 0.52 and an average sound insulation loss of 38.6db;

2. The composite structure can significantly improve the acoustic performance of textile materials, and the three-layer composite structure (surface wool polyester blended fabric+intermediate needle punched nonwovens+bottom cotton fabric) has the best comprehensive performance, with the average sound absorption coefficient increased by 25% and the sound insulation loss increased by 18.6% compared with the single blended material;

3. There is an optimal value for the thickness and area density of textile materials. When the thickness is 4.5mm and the area density is 550g/m^2, the acoustic performance and economy reach a balance;

4. The optimized textile materials show excellent application effects in different singing scenes. Compared with traditional acoustic materials, the clarity, fullness and pene-

tration of singing sound are significantly improved, and the overall satisfaction is improved by 12% -15%.

AUTHOR CONTRIBUTIONS

Conceptualization –Ru Li, Bat-Erdene and Mingyang Zhang; methodology – Ru Li, Bat-Erdene and Mingyang Zhang; investigation – Ru Li, Bat-Erdene and Mingyang Zhang; writing-original draft preparation – Ru Li, Bat-Erdene and Mingyang Zhang. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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