Study on Standards of Ceramic Knives in Contact with Foodstuffs Part 1: Material and Structure

Geping Bi1,a, Wenniu Huang1, Zhe Yang2 and Aijin Ma3,b,*

1China National Quality Supervision and Inspection Center for Knife, Scissors and Domestic Metal Tool, Yangjiang, 529539, China
2China National Accreditation Service for Conformity Assessment, Beijing, 100062
3China National Institute of Standardization, Beijing, 100191
Email: a bigeping@sina.com, b maaj@cnis.gov.cn

Abstract. In this paper, the material and structure requirements of ISO 8442-9 standard have been studied, and the principles for determining the ISO 8442-9 standard technical requirements have been analyzed, according to the test results of different specifications of ceramic knives from 22 production enterprises in 6 countries, and incorporating the opinions and suggestions from 6 countries including production enterprises, technology experts, consumers, international trade, etc.

1. Introduction
Ceramic knives that came in contact with food were born in Japan in the 1980s [1-2], extending to daily ceramics from industrial zirconia ceramics. Zirconia ceramic knives have the advantages of high sharpness, high wear resistance, corrosion resistance, and cutting food without peculiar smell, etc. [1-8]. After more than 30 years of development, ceramic knives have been widely used in countries all over the world. China, Britain, France, Germany, Japan, South Korea, the United States and other countries have formed their own branded products.

On March 10th, 2014, the International Standardization Organization for Cutlery and table and decorative metal hollow-ware technical committee (ISO/TC186) voted to draft jointly by China for standardization technical committee and "ISO/TC186 Technical Committee on ISO 8442-9 Materials and articles in contact with foodstuffs - Cutlery and table holloware - Part 9: Requirements for ceramic knives" standard, namely ISO 8442-9 Technical requirements for ceramic knife for food contact materials and products, and a standard drafting working group has been established that consists of technical experts from the cutting tool industry in China, the United Kingdom, France and Germany that come into contact with food. After more than three years of hard working, the technical requirements of ceramic knife are basically determined.

The technical requirements for ceramic knives are the technical requirements for preparing and preparing food knives consisting of ceramic blades with knife edge and handles that come into contact with food, and specify the materials and performance requirements and test methods for ceramic knives used in food preparation.

ISO 8442-1:1998 Materials and Articles In Contact With Foodstuffs - Cutlery and Table Holloware - Part 1: Requirements for Cutlery for the Preparation of Food [9], which specifies the technical requirements for food contact with metal cutting tools. Based on ISO 8442-1, ISO 8442-9 shall be compiled in combining with the characteristics of ceramics, new testing techniques and the use of food
contact tools. Based on the characteristics of ceramic knives, all technical parameter requirements and test methods are required for ceramic knives, and no specific requirements are put forward for raw materials and production processes of ceramic knives.

This paper has been studied on 4 aspects from the materials, porosity, appearance and crack, and cutting edge angle of the food ceramic knife, and the test methods were determined, and the principle of ISO 8442-9 technical requirements was evaluated and analyzed.

2. Material
Regarding ceramics, ISO 20507: 2003 is defined as an inorganic non-metallic material made from natural minerals or chemical products as a raw material and processed by raw materials, formed, dried and burned. The concept of ceramics includes products made of clay as raw materials and products made of oxides, nitrides, carbides, silicides, borides, etc. [10]

At present, the ceramic knife blade is basically made of yttrium oxide compound zirconia. The mass fraction of Zr (Hf) O₂ is 82%-96% and that of Y₂O₃ is 4%-18%. In order to encourage the application of new materials and new techniques for ceramic knives, ISO 8442-9 does not stipulate specific types of ceramics, the content of ceramic chemical composition and the production process of ceramic knife.

The specific requirements of ISO 8442-9 for ceramic knife materials are: applications of ceramic blade can ensure that the finished product meets all the performance requirements of this standard.

3. Structure

3.1. Porosity
Based on the characteristics of the production process of the ceramic knife, there are certain pores in the ceramic blade. The pore is an important parameter that affects the performance of the ceramic knife, and directly affects the index of sharpness, edge retention, brittleness, and the like of the ceramic knife.

There are two opinions on the detection method of porosity, the first one is based on the Archimedes principle, the volume is measured by the drainage method, the weight is measured by a precision balance, and the volume density and the open porosity are calculated [11-17] and converted. The second method is the metallographic method. According to the principle of stereology, the volume fraction of the phase in the three-dimensional space is determined from the two-dimensional parameters measured and calculated on the surface of the metallographic specimen [18-22].

ISO 8442-9 has no limitation on the ceramic material, i.e., the definition of the theoretical density and the actual density, the detection of volume density and the open porosity have no practical significance, and the relative density that determines the performance is the porosity. The ISO 18754 fine ceramic density and apparent porosity test method clearly stipulates that when the apparent porosity is less than 0.5%, the measurement is inaccurate [17], the detection of natural porosity is inaccurate, and the porosity less than 0.5% had a great influence on the ceramic knife sharpness and edge retention (the minimum porosity in the sample is 0.04%). When the metallographic method is used to detect the porosity, the content that can be detected also includes the size, shape and distribution of the pores. Therefore, ISO 8442-9 specifies the metallographic method for the detection of porosity [22].

The results of sample metallographic detecting pores is: minimum porosity 0.04%, maximum porosity 3.78%, maximum pore size 43 μm, pores are round, oval, flat, trapezoidal, polygonal and other shapes, pores have no apparent uneven distribution on the whole field surface and the core. The porosity in the sample is arranged in ascending order and a distribution map is formed, see Figure 1. Porosity of ceramic knife as shown in Figure 2.
The specific requirements of ISO 8442-9 on the porosity of ceramic knives are: the porosity of the ceramic blades should be ≤ 1.5%, the maximum projection length of the largest pore (maximum pore size) should be ≤ 25 μm, and inclusions or tissue defects in the microstructure cannot be observed in the field of view of the observed pores (Micro cracks, uneven pore distribution, etc.). The specific metallographic detection method is to observe the entire detection surface on the microscope, if inclusions or microscopic defects are found, the maximum projection length (maximum pore size) should be recorded and measured at the atmospheric hole, and the porosity should be determined by selecting the field of view with the most pores. When the porosity is measured, the image analyzer can be used for quantitative analysis, and the spectrum comparison method can also be used for semi-quantitative analysis. Figure 2b is a typical diagram of 1.5% porosity, and the reference diagram for semi-quantitative analysis was placed in the appendix of ISO 8442-9.

Porosity has a great influence on the sharpness and edge retention of the ceramic knife. When the porosity is less than 0.1%, the sharpness of the ceramic knife is as high as 100 mm. When the porosity is greater than 0.5%, the sharpness is reduced to 50 mm and the drop is significant. After the porosity is ≥ 1%, the sharpness is basically kept at 30 mm. It is shown that when the porosity is less than 0.5%,
the porosity has a great influence on the sharpness of the ceramic knife, while the porosity is ≥1%, and the porosity of the ceramic knife has little effect on the sharpness of the ceramic knife [22].

In the sample, the ceramic knife with a porosity of more than 1.5%, its sharpness and edge retention cannot meet the technical requirements. On the premise of performance requirements of ceramic knives, the technical requirements for porosity and maximum dimensions are proposed to guide manufacturers in controlling process parameters, ensuring compliance of performance indicators, and ensuring the safety of use.

3.2. Cutting edge angle

The size of the cutting edge angle of the ceramic knife directly affects the sharpness, edge retention and safety of use. The smaller the cutting edge angle is, the greater the sharpness, but the greater the risk of cutting edge angle collapse. The relationship between cutting edge angle and sharpness, edge retention is shown in Figure 3 and Figure 4: The results of sample cutting edge angle detection are arranged in ascending order to obtain a distribution map. See Figure 5. The minimum cutting edge angle is 25.7° and the maximum cutting edge angle is 86.8°.

![Figure 3. Ceramic knife cutting edge angle and sharpness.](image)

![Figure 4. Ceramic knife cutting edge angle and edge retention.](image)

Specified in ISO 8442-1 standard, the cutting edge angle should not exceed 40° and measured at a distance of 1 mm from the edge, away from the handle is not less than 25 mm, the thickness should not exceed 0.46 mm. According to the test results of the sample, the sharpness and edge retention of the samples satisfied the requirements of ISO 8442-9; its cutting edge angle has also satisfied the requirements of the ISO 8442-1 standard. Cutting edge angle is in the design category of ceramic knife, ISO 8442-9 does not make mandatory requirements. At first, the requirements of cutting edge angle
were initially taken as a remark in the requirements of the ceramic knife structure in the ISO 8442-1 standard, but were easily misunderstood and were finally taken as a proposed clause.

![Graph showing cutting edge angle distribution of ceramic knife.](image)

**Figure 5.** The cutting edge angle distribution of ceramic knife.

### 3.3. Appearance and cracks

In terms of defects in ceramics, the National Standards of China GB/T 3303-1982 has detailed provisions for the defects of ceramics for daily use [23], and there are 47 defective terms. The defects found on ceramic knives at present include color specks, pores, deformation (distortion), scratches, cracks, stains, burrs, and chips. See Figure 6 for an example of typical macroscopic defects of ceramic knife.

![Images of ceramic knife defects.](image)

**Figure 6.** The typical macroscopic defects of ceramic knife.

In order to meet the requirements of different users, the appearance design of ceramic knives has a special structural shape, color, and this structure, shape; color will be confused with the defects, made the differences in the detection of conformity assessment. Therefore, ISO 8442-9 stipulates that there should be no defects that can make the product unable to meet the performance requirements. The defects include but are not limited to: specks, pores, deformation (distortion), scratches, cracks, stains, burrs, and chips, etc.

Ceramic is brittle material, and cracks on ceramic blade is the greatest potential trouble of safe use. No cracks appear on the ceramic blade, regardless of crack size. In the metallographic examination of porosity, micro cracks can be detected. For macro-cracks, the conventional test method is visual...
inspection (Figure 6c) or red-absorption test (Figure 7a). However, these two methods can only be used to detect cracks in white ceramic knives and cannot be applied to color ceramic knives such as black and green ceramic knives [24]. Therefore, ISO 8442-9 applies penetration testing of non-destructive testing method and stipulates that: for ceramic blade, penetration testing shall be carried out in accordance with the ISO 3452-1 standard method [25]; Ceramic blade shall be free of defects such as cracks, porosity, and breakage. Figure 7b) is a crack on the black ceramic blade detected by this method.

![a) The crack defects detected by red-absorption test. b) The crack defects detected by penetrated test.](image)

**Figure 7.** The crack defects of ceramic knife.

4. Conclusion
Since the first successful development of the ceramic knife in contact with foodstuffs and the international standardization of the “Technical Requirements for the ceramic knife in contact with foodstuffs”, the development of the ceramic knife has gone through more than 30 years. In the course of the research on the performance of ceramic knives, the working group has absorbed the opinions of production companies, technical experts, consumers, and international trade in six countries around the world, based on the detection results of ceramic knives of 55 specifications of 22 international companies, researched and determined the technical requirements of the 4 aspects of the food ceramic knife, and determined the principle of ISO 8442-9 technical requirements.

The promulgation of international standards for the ceramic knife in contact with foodstuffs requires an important role in helping product quality improvement, ensuring user safety, promoting the development of production companies, and facilitating international economic and trade exchanges.

5. References
[1] Jiang Lingling. Ceramic knives are not invisible knives-analysis of identification capability of ceramic knives by security equipment [J]. China Security & Protection, P.73-76, vol. 9 (10), 2014.
[2] Chen Daming. Injection Technology and application of Advanced Ceramic materials [M]. Defense Industry Press, P.120-121, 2011, Beijing, China.
[3] Xiong Lu,TRIZ theory innovation design of painted ceramic knives [J]. China Ceramics, P. 23-29, vol.46 (8), 2010.
[4] Huang Hui, Wei Bin, et al. Effects of Two-Step Method on Properties of Zirconia Ceramic [J]. West China Journal of Stomatology, P. 23-29, vol.26 (2), Apr. 2008.
[5] Yu Xinmeng, Xu Baokui,Yuan Fade. Stabilizing and Applications of Zirconia [J]. Rare Metals Letters, P.23-29, 26 (1), 2007.
[6] Liang Xiaoping, Yang Zhengfang. Research Progress on Characteristics Of Y-TZP [J]. Bulletin of the Chinese Ceramic Society, P.23-29, vol. 24 (3), 2003.
[7] Zhao Yibin, Comprehensive Dictionary of Material [M]. Chemical Industry Press, P. 579-580, 1994, Beijing, China.
[8] Li Xiaoyan Preparation of zirconia ceramic knives by injection molding [J]. Foshan Ceramics, P.13-14, vol. 23 (9), 2003.
[9] BS EN ISO 8442-1:1998, Materials and articles in contact with foodstuffs - Cutlery and table hollowware - Part 1: Requirement for cutlery for the preparation of food [S].
[10] ISO 20507: 2003 Fine ceramics (advanced ceramics, advanced technical ceramics) – Vocabulary [S].
[11] Huang Peiyun. Principle of Powder Metallurgy [M]. Metallurgical Industry Press, 2006, P.370-397, Beijing, China.
[12] Jin Zhihao, Gao Jiqiang, Qiao Guanjun. Engineering Ceramics [M]. Xi'an Jiaotong University Press, 2000, P.51-52, Xi'an, China.
[13] Shen Botao, Lei Yi, Fang Shuming. Density Determination for Metallurgical Powder Material [J]. Mining and Metallurgy, P.106-110, vol. 21 (2), 2012.
[14] GB/T 2413-1980 Piezoelectric ceramic materials--Measuring methods for determination of volume density [S].
[15] ISO 10545-3:1995 Ceramic tiles-Part 3: Determination of water absorption, apparent porosity, apparent relative density and bulk density [S].
[16] ISO 2738:1999 Sintered metal materials, excluding hardmetals - Permeable sintered metal materials ---Determination of density, oil content, and open porosity [S].
[17] ISO 18754:2003 Fine ceramics (advanced ceramics, advanced technical ceramics) - Determination of density and apparent porosity [S].
[18] GB/T 15749-2008 Measuring method in quantitative metallography [S].
[19] Song Fuchang. Metallographic Examination on High Performance Ceramics - Specimen Preparation, Etching Technology and Microstructure [J], Development and Application of Materials, P22-25, vol.11(2),1996.
[20] GB/T 13298-2015 Inspection methods of microstructure for metals [S].
[21] ISO 4505:1978. Hardmetals-Metallographic determination of porosity and uncombined carbon.
[22] Ge-Ping BI, Wen-Hua TAN, Ai-Jin MA. Metallographic Determination for Porosity of Zirconia Ceramic Knives [J]. Applied Mechanics and Materials, P.20-25, vol.873, 2017.
[23] GB/T 3303-1982 Terms used of defects of domestic ceramic ware[S].
[24] Zhang Canying. Preparation of Colored Zirconia Ceramics [J], Rare Metal Materials and Engineering, p266-268, vol. 36 (Suppl.1), 2007.
[25] ISO 3452-1:2013, Non-destructive testing - Penetrant testing - Part 1: General principles[S].