Research Progress on Chemical Constituents of Zingiber officinale Roscoe

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Zingiber officinale Roscoe (ZOR, also Shengjiang in Chinese) is a perennial herb from the Zingiberaceae family, native to the Pacific Islands. It can be found in the Chinese provinces of Shandong, Henan, Hubei, Yunnan, Guangdong, Sichuan, and Jiangsu. ZOR is the fresh root of ginger, which is not only an important condiment but also one of the most commonly used Chinese medicines in clinical practice. Traditional Chinese medicine believes that ZOR has effects of releasing exterior and dissipating cold, arresting vomiting, resolving phlegm, and relieving coughs and can be used to treat fish and crab poison, stomach colds and vomiting, and cold sputum cough [1]. Modern pharmacological studies have shown that ZOR can promote digestion, improve blood circulation, lower blood lipids, lower blood sugar, relieve vestibular stimulation, and provide anti-inflammatory, antitumor, antimicrobial, and antioxidant effects [2–5]. Due to its rich active constituents, ZOR has been used in cosmetics [6], toothpaste [7], and health foods [8–10].

All development and utilization of ZOR are based on its material composition. The chemical composition of ZOR is complex, includes more than 300 types of species, and can be broadly divided into three categories: volatile oils, gingerol, and diarylheptanoids [11–13]. In this paper, the existing research literature of ZOR is systematically summarized, and each chemical composition and its chemical structure are listed in detail, with a view to providing references for quality control, cultivation production, and further development of ZOR.

1. Introduction

Zingiber officinale Roscoe (ZOR, also Shengjiang in Chinese) is a perennial herb from the Zingiberaceae family, native to the Pacific Islands. It can be found in the Chinese provinces of Shandong, Henan, Hubei, Yunnan, Guangdong, Sichuan, and Jiangsu. ZOR is the fresh root of ginger, which is not only an important condiment but also one of the most commonly used Chinese medicines in clinical practice. Traditional Chinese medicine believes that ZOR has effects of releasing exterior and dissipating cold, arresting vomiting, resolving phlegm, and relieving coughs and can be used to treat fish and crab poison, stomach colds and vomiting, and cold sputum cough [1]. Modern pharmacological studies have shown that ZOR can promote digestion, improve blood circulation, lower blood lipids, lower blood sugar, relieve vestibular stimulation, and provide anti-inflammatory, antitumor, antimicrobial, and antioxidant effects [2–5]. Due to its rich active constituents, ZOR has been used in cosmetics [6], toothpaste [7], and health foods [8–10].

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2. Constituents

2.1. Volatile Oils. Volatile oils, also known as ginger essential oils, are generally composed of terpenoids [14]. Ginger essential oils give ZOR a unique aromatic smell [11]. The volatile oil composition varies based on where the ZOR is harvested. Currently, the ingredients identified in the volatile oils of ZOR and their chemical structures are shown in Table 1.

2.2. Gingerol. Gingerol is the spicy component of ZOR. It is a mixture of various substances, all of which contain the 3-methoxy-4-hydroxyphenyl functional group. Gingerols can be divided into gingerols, shogaols, paradols, zingerones, gingerdiones, and gingerdiols, according to the different fatty chains connected by this functional group [28, 29]. The structural formulas are given in Table 2.
| No. | Type   | Name                        | Structure | Reference |
|-----|--------|-----------------------------|-----------|-----------|
| 1   | Terpene| α-Terpinene                 | ![Structure](image1.png) | [15]      |
| 2   | Terpene| α-Terpineol                 | ![Structure](image2.png) | [15]      |
| 3   | Terpene| 4-Terpineol                 | ![Structure](image3.png) | [15]      |
| 4   | Terpene| Terpinolene                 | ![Structure](image4.png) | [15]      |
| 5   | Terpene| γ-Terpinolene               | ![Structure](image5.png) | [15]      |
| 6   | Alcohol| Cineole                     | ![Structure](image6.png) | [15]      |
| 7   | Alcohol| β-Eudesmol                  | ![Structure](image7.png) | [15]      |
| 8   | Alcohol| Nerol                       | ![Structure](image8.png) | [15]      |
| 9   | Alcohol| *trans*-Nerolidol           | ![Structure](image9.png) | [15]      |
| 10  | Alcohol| 4-Isopropylbenzyl alcohol   | ![Structure](image10.png) | [15]      |
| 11  | Alcohol| 3,7-Dimethylocta-1,6-dien-3-ol | ![Structure](image11.png) | [15]      |
| 12  | Alcohol| 3,7-Dimethyloct-6-en-1-yn-3-ol | ![Structure](image12.png) | [15]      |
| 13  | Alcohol| 3-Methylhexan-2-ol          | ![Structure](image13.png) | [15]      |
| 14  | Alcohol| *cis*-Piperitol             | ![Structure](image14.png) | [15]      |
| No. | Type     | Name                                         | Structure | Reference |
|-----|----------|----------------------------------------------|-----------|-----------|
| 15  | Alcohol  | Borneol                                      | ![Structure](image) | [15]       |
| 16  | Alcohol  | Elemol                                       | ![Structure](image) | [15]       |
| 17  | Alcohol  | tau-Murolol                                  | ![Structure](image) | [15]       |
| 18  | Alcohol  | 2-Methoxy-1,7,7-trimethylbicyclo[2.2.1]heptane | ![Structure](image) | [15]       |
| 19  | Alcohol  | 1-Isopropyl-4-methylcyclohex-3-enol          | ![Structure](image) | [15]       |
| 20  | Alcohol  | 2-Tetradecanol                               | ![Structure](image) | [15]       |
| 21  | Alcohol  | Myrtenol                                     | ![Structure](image) | [15]       |
| 22  | Alcohol  | Citronellol                                  | ![Structure](image) | [15]       |
| 23  | Alcohol  | Geraniol                                     | ![Structure](image) | [15]       |
| 24  | Alcohol  | cis-Linalool oxide                           | ![Structure](image) | [15]       |
| 25  | Alcohol  | 4-Ethoxybutan-1-ol                           | ![Structure](image) | [15]       |
| 26  | Alcohol  | α-Eudesmol                                   | ![Structure](image) | [15]       |
| 27  | Alcohol  | Nerolidol                                    | ![Structure](image) | [15]       |
| 28  | Alcohol  | Farnesol                                     | ![Structure](image) | [15]       |
| 29  | Alcohol  | trans-4-Isopropyl-1-methyl-2-cyclohexen-1-ol | ![Structure](image) | [15]       |
| No. | Type      | Name                                | Structure | Reference |
|-----|-----------|-------------------------------------|-----------|-----------|
| 30  | Alcohol   | cis-4-Isopropyl-1-methyl-2-cyclohexen-1-ol | ![Structure](image1) | [15]      |
| 31  | Alcohol   | 2-Heptanol                          | ![Structure](image2) | [16]      |
| 32  | Alcohol   | 1-Methoxy-2-methyl                  | ![Structure](image3) | [16]      |
| 33  | Alcohol   | cis-Sesquisabinene hydrate          | ![Structure](image4) | [17]      |
| 34  | Alcohol   | cis-2-p-Menthen-1-ol                | ![Structure](image5) | [17]      |
| 35  | Alcohol   | endo-Borneol                        | ![Structure](image6) | [17]      |
| 36  | Alcohol   | trans-Sabinene hydrate              | ![Structure](image7) | [17]      |
| 37  | Alcohol   | 2-Nonanol                           | ![Structure](image8) | [18]      |
| 38  | Alcohol   | Propanol                            | ![Structure](image9) | [18]      |
| 39  | Alcohol   | cis-β-Sesquiphellandrol            | ![Structure](image10) | [18]      |
| 40  | Alcohol   | trans-β-Sesquiphellandrol          | ![Structure](image11) | [18]      |
| 41  | Alcohol   | β-Santalol                          | ![Structure](image12) | [19]      |
| 42  | Alcohol   | Zingiberol                          | ![Structure](image13) | [19]      |
| 43  | Alcohol   | tau-Cadinol                         | ![Structure](image14) | [20]      |
| No. | Type      | Name                          | Structure | Reference |
|-----|-----------|-------------------------------|-----------|-----------|
| 44  | Alcohol   | Zingiberenol                  | ![Structure](image1) | [21]      |
| 45  | Alcohol   | 2-Pinen-5-ol                 | ![Structure](image2) | [21]      |
| 46  | Alcohol   | Bornyl methyl ether           | ![Structure](image3) | [21]      |
| 47  | Alcohol   | Isoborneol                    | ![Structure](image4) | [22]      |
| 48  | Alcohol   | 2-Decanol                     | ![Structure](image5) | [22]      |
| 49  | Alcohol   | Fenchol                       | ![Structure](image6) | [22]      |
| 50  | Alcohol   | Linalool                      | ![Structure](image7) | [23]      |
| 51  | Alcohol   | Plinol                        | ![Structure](image8) | [23]      |
| 52  | Alcohol   | Camphenol                     | ![Structure](image9) | [23]      |
| 53  | Alcohol   | trans-2-Decen-1-ol            | ![Structure](image10) | [23]      |
| 54  | Alcohol   | Hentriacontanol               | ![Structure](image11) | [24]      |
| 55  | Alcohol   | 10-O-β-D-Glucopyranosyl-hydroxyl cineole | ![Structure](image12) | [25]      |
| 56  | Aldoketone | Butanal                       | ![Structure](image13) | [15]      |
| 57  | Aldoketone | Germacrone                    | ![Structure](image14) | [15]      |
| 58  | Aldoketone | 2,6-Dimethylhept-5-enal       | ![Structure](image15) | [15]      |
| 59  | Aldoketone | 2-Heptanone                   | ![Structure](image16) | [15]      |
| No. | Type         | Name                                | Structure | Reference |
|-----|--------------|-------------------------------------|-----------|-----------|
| 60  | Aldoketone   | (E)-Citral                          | ![Structure](image1) | [15]      |
| 61  | Aldoketone   | (Z)-Citral                          | ![Structure](image2) | [15]      |
| 62  | Aldoketone   | 2-Nonanone                          | ![Structure](image3) | [15]      |
| 63  | Aldoketone   | 3-((3E,5E)-Deca-3,5-dienyl)cyclopentanone | ![Structure](image4) | [15]      |
| 64  | Aldoketone   | β-Cyclocitral                       | ![Structure](image5) | [15]      |
| 65  | Aldoketone   | 2-Undecanone                        | ![Structure](image6) | [15]      |
| 66  | Aldoketone   | 1,7,7-Trimethylbicyclo[2.2.1]heptan-2-one | ![Structure](image7) | [15]      |
| 67  | Aldoketone   | (1R)-(−)-Myrtenal                   | ![Structure](image8) | [15]      |
| 68  | Aldoketone   | β-Citronellal                       | ![Structure](image9) | [15]      |
| 69  | Aldoketone   | Crypton                             | ![Structure](image10) | [15]      |
| 70  | Aldoketone   | 4-Isopropylcyclohex-2-enone         | ![Structure](image11) | [15]      |
| 71  | Aldoketone   | Camphor                             | ![Structure](image12) | [15]      |
| 72  | Aldoketone   | 6-Methyl-5-hepten-2-one             | ![Structure](image13) | [15]      |
| 73  | Aldoketone   | trans,trans-Farnesal                | ![Structure](image14) | [15]      |
| 74  | Aldoketone   | Hexanal                             | ![Structure](image15) | [16]      |
| 75  | Aldoketone   | Neral                               | ![Structure](image16) | [17]      |
| No. | Type      | Name                  | Structure | Reference |
|-----|-----------|-----------------------|-----------|-----------|
| 76  | Aldoketone| Geranial              | ![Geranial Structure](#) | [17]       |
| 77  | Aldoketone| Octanal               | ![Octanal Structure](#) | [17]       |
| 78  | Aldoketone| Methyl heptenone      | ![Methyl Heptenone Structure](#) | [18]       |
| 79  | Aldoketone| Nonyl aldehyde        | ![Nonyl Aldehyde Structure](#) | [18]       |
| 80  | Aldoketone| Acetaldehyde          | ![Acetaldehyde Structure](#) | [18]       |
| 81  | Aldoketone| Propionaldehyde       | ![Propionaldehyde Structure](#) | [18]       |
| 82  | Aldoketone| Valeraldehyde         | ![Valeraldehyde Structure](#) | [18]       |
| 83  | Aldoketone| Perillal              | ![Perillal Structure](#) | [19]       |
| 84  | Aldoketone| (E)-Dodec-2-enal      | ![Dodec-2-enal Structure](#) | [21]       |
| 85  | Aldoketone| (Z)-3,7-Dimethylocta-3,6-dienal | ![3,7-Dimethylocta-3,6-dienal Structure](#) | [21]       |
| 86  | Aldoketone| (E)-3,7-Dimethylocta-3,6-dienal | ![3,7-Dimethylocta-3,6-dienal Structure](#) | [21]       |
| 87  | Aldoketone| (E)-Dec-2-enal        | ![Dec-2-enal Structure](#) | [21]       |
| 88  | Aldoketone| Decanal               | ![Decanal Structure](#) | [23]       |
| 89  | Aldoketone| Citronella            | ![Citronella Structure](#) | [23]       |
| 90  | Aldoketone| 2-Octenal             | ![2-Octenal Structure](#) | [21]       |
| 91  | Aldoketone| Octanal               | ![Octanal Structure](#) | [26]       |
| 92  | Aldoketone| Acetone               | ![Acetone Structure](#) | [26]       |
| 93  | Acid      | L-Bornyl acetate      | ![L-Bornyl Acetate Structure](#) | [15]       |
| 94  | Acid      | Geranic acid          | ![Geranic Acid Structure](#) | [15]       |
| 95  | Acid      | Undecanoic acid       | ![Undecanoic Acid Structure](#) | [16]       |
| No. | Type | Name                          | Structure | Reference |
|-----|------|-------------------------------|-----------|-----------|
| 96  | Ester| Neryl acetate                 | ![Structure](/TableCell/02) | [15]       |
| 97  | Ester| Methyl 11-(cyclopent-2-enyl)undecanoate | ![Structure](/TableCell/03) | [15]       |
| 98  | Ester| Geranyl propionate            | ![Structure](/TableCell/04) | [15]       |
| 99  | Ester| endo-Bornyl acetate           | ![Structure](/TableCell/05) | [15]       |
| 100 | Ester| sec-Butyl acetate             | ![Structure](/TableCell/06) | [15]       |
| 101 | Ester| 3,7-Dimethyl-2,6-octadienyl acetate | ![Structure](/TableCell/07) | [15]       |
| 102 | Ester| Neryl propionate              | ![Structure](/TableCell/08) | [15]       |
| 103 | Ester| Geraniol formate              | ![Structure](/TableCell/09) | [15]       |
| 104 | Ester| Myrtenyl acetate              | ![Structure](/TableCell/10) | [15]       |
| 105 | Ester| Geranyl acetate               | ![Structure](/TableCell/11) | [15]       |
| 106 | Ester| Formic acid ethyl ester       | ![Structure](/TableCell/12) | [16]       |
| 107 | Ester| Ethyl butanoate               | ![Structure](/TableCell/13) | [17]       |
| 108 | Ester| Citronellyl acetate           | ![Structure](/TableCell/14) | [17]       |
| 109 | Ester| Heptyl acetate                | ![Structure](/TableCell/15) | [17]       |
| 110 | Ester| Methyl acetate                | ![Structure](/TableCell/16) | [18]       |
| 111 | Ester| Ethyl acetate                 | ![Structure](/TableCell/17) | [18]       |
| No. | Type       | Name                  | Structure | Reference |
|-----|------------|-----------------------|-----------|-----------|
| 112 | Ester      | Butyl acetate         | ![Structure](image1.png) | [21]      |
| 113 | Ester      | 2-Octyl acetate       | ![Structure](image2.png) | [21]      |
| 114 | Fat hydrocarbon | allo-Aromadendrene   | ![Structure](image3.png) | [15]      |
| 115 | Fat hydrocarbon | β-Sesquiphellandrene | ![Structure](image4.png) | [15]      |
| 116 | Fat hydrocarbon | α-Cedrene             | ![Structure](image5.png) | [15]      |
| 117 | Fat hydrocarbon | β-Thujene             | ![Structure](image6.png) | [15]      |
| 118 | Fat hydrocarbon | Cadina-5,8-diene      | ![Structure](image7.png) | [15]      |
| 119 | Fat hydrocarbon | Bicyclo[2.2.1]heptane | ![Structure](image8.png) | [15]      |
| 120 | Fat hydrocarbon | (E)-2,7-Dimethyloct-3-en-5-yne | ![Structure](image9.png) | [15]      |
| 121 | Fat hydrocarbon | (Z)-2,6-Dimethylocta-2,6-diene | ![Structure](image10.png) | [15]      |
| 122 | Fat hydrocarbon | (E)-3,7-Dimethylocta-1,3,6-triene | ![Structure](image11.png) | [15]      |
| 123 | Fat hydrocarbon | β-Phellandrene        | ![Structure](image12.png) | [15]      |
| 124 | Fat hydrocarbon | α-Bergamotene         | ![Structure](image13.png) | [15]      |
| 125 | Fat hydrocarbon | α-Gurjunene           | ![Structure](image14.png) | [15]      |
| 126 | Fat hydrocarbon | Sabinene              | ![Structure](image15.png) | [15]      |
| No. | Type            | Name                  | Structure | Reference |
|-----|-----------------|-----------------------|-----------|-----------|
| 127 | Fat hydrocarbon | (+)-Cyclosativene     | ![Structure Image](image1) | [15]      |
| 128 | Fat hydrocarbon | (Z)-β-Farnesene       | ![Structure Image](image2) | [15]      |
| 129 | Fat hydrocarbon | (E)-β-Farnesene       | ![Structure Image](image3) | [15]      |
| 130 | Fat hydrocarbon | (Z,Z)-α-Farnesene     | ![Structure Image](image4) | [15]      |
| 131 | Fat hydrocarbon | Zingiberene           | ![Structure Image](image5) | [15]      |
| 132 | Fat hydrocarbon | α-Farnesene           | ![Structure Image](image6) | [15]      |
| 133 | Fat hydrocarbon | (E)-5-Methylocta-1,6-diene | ![Structure Image](image7) | [15]      |
| 134 | Fat hydrocarbon | 5-Methyloct-3-yne     | ![Structure Image](image8) | [15]      |
| 135 | Fat hydrocarbon | 7-Methylocta-3,4-diene | ![Structure Image](image9) | [15]      |
| 136 | Fat hydrocarbon | γ-Elemene             | ![Structure Image](image10) | [15]      |
| 137 | Fat hydrocarbon | γ-Humulene            | ![Structure Image](image11) | [15]      |
| 138 | Fat hydrocarbon | Thujopsene            | ![Structure Image](image12) | [15]      |
| 139 | Fat hydrocarbon | β-Elemene             | ![Structure Image](image13) | [15]      |
| 140 | Fat hydrocarbon | β-Bisabolene          | ![Structure Image](image14) | [15]      |
| 141 | Fat hydrocarbon | α-Pinene              | ![Structure Image](image15) | [15]      |
| 142 | Fat hydrocarbon | β-Pinene              | ![Structure Image](image16) | [15]      |
| No. | Type          | Name                       | Structure | Reference |
|-----|---------------|----------------------------|-----------|-----------|
| 143 | Fat hydrocarbon | Caryophyllene              | ![Structure](structure143) | [15]       |
| 144 | Fat hydrocarbon | β-Caryophyllene            | ![Structure](structure144) | [15]       |
| 145 | Fat hydrocarbon | Tricyclene                 | ![Structure](structure145) | [15]       |
| 146 | Fat hydrocarbon | Moslene                    | ![Structure](structure146) | [15]       |
| 147 | Fat hydrocarbon | Cedrene                    | ![Structure](structure147) | [15]       |
| 148 | Fat hydrocarbon | (−)-allo-Aromadendrene     | ![Structure](structure148) | [15]       |
| 149 | Fat hydrocarbon | Neoclovene                 | ![Structure](structure149) | [15]       |
| 150 | Fat hydrocarbon | 3-Octyne                   | ![Structure](structure150) | [15]       |
| 151 | Fat hydrocarbon | 1-Octene                   | ![Structure](structure151) | [15]       |
| 152 | Fat hydrocarbon | β-Myrcene                  | ![Structure](structure152) | [15]       |
| 153 | Fat hydrocarbon | β-Eudesmene                | ![Structure](structure153) | [15]       |
| 154 | Fat hydrocarbon | Eudesma-3,7(11)-diene      | ![Structure](structure154) | [15]       |
| 155 | Fat hydrocarbon | Caryophyllene              | ![Structure](structure155) | [15]       |
| 156 | Fat hydrocarbon | Bicyclo[3.1.1]heptane      | ![Structure](structure156) | [15]       |
| 157 | Fat hydrocarbon | 1-Cyclopropylpentane       | ![Structure](structure157) | [15]       |
| 158 | Fat hydrocarbon | 3-Carene                   | ![Structure](structure158) | [15]       |
| No. | Type           | Name                       | Structure | Reference |
|-----|----------------|----------------------------|-----------|-----------|
| 159 | Fat hydrocarbon | 2-Carene                   | ![Structure](Image) | [15]      |
| 160 | Fat hydrocarbon | (+)-Aromadendrene          | ![Structure](Image) | [15]      |
| 161 | Fat hydrocarbon | Fenchene                   | ![Structure](Image) | [16]      |
| 162 | Fat hydrocarbon | δ-Elemene                  | ![Structure](Image) | [17]      |
| 163 | Fat hydrocarbon | D-Limonene                 | ![Structure](Image) | [18, 22]  |
| 164 | Fat hydrocarbon | β-Phellandrene             | ![Structure](Image) | [18, 26]  |
| 165 | Fat hydrocarbon | 10-Epizonarene             | ![Structure](Image) | [18]      |
| 166 | Fat hydrocarbon | Octane                     | ![Structure](Image) | [18]      |
| 167 | Fat hydrocarbon | Nonane                     | ![Structure](Image) | [18]      |
| 168 | Fat hydrocarbon | α-Bergamotene              | ![Structure](Image) | [19]      |
| 169 | Fat hydrocarbon | β-Bisabolene               | ![Structure](Image) | [20]      |
| 170 | Fat hydrocarbon | τ-Epi-α-selinene           | ![Structure](Image) | [20]      |
| 171 | Fat hydrocarbon | 4-Carene                   | ![Structure](Image) | [22]      |
| 172 | Fat hydrocarbon | Camphene                   | ![Structure](Image) | [23]      |
| 173 | Fat hydrocarbon | α-Phellandrene             | ![Structure](Image) | [23]      |
| 174 | Fat hydrocarbon | (Z)-3,7-Dimethylocta-1,3,6-triene | ![Structure](Image) | [27]      |
| No. | Type          | Name           | Structure | Reference |
|-----|---------------|----------------|-----------|-----------|
| 175 | Fat hydrocarbon | Germacrene     | ![Germacone](image) | [27]       |
| 176 | Fat hydrocarbon | δ-Cadinene     | ![Cadinene](image) | [26]       |
| 177 | Fat hydrocarbon | α-Cubebene     | ![Cubebene](image) | [26]       |
| 178 | Fat hydrocarbon | α-Copaene      | ![Copaene](image)  | [26]       |
| 179 | Arene         | α-Curcumene    | ![Curcumene](image) | [15]       |
| 180 | Arene         | 2-Isopropyltoluene | ![Isopropyltoluene](image) | [15]       |
| 181 | Arene         | o-Cymene       | ![Cymene](image) | [15]       |
| 182 | Arene         | Styrene        | ![Styrene](image) | [17]       |
| 183 | Arene         | Methylbenzene  | ![Methylbenzene](image) | [17]       |
| 184 | Arene         | Cumene         | ![Cumene](image) | [18]       |
| 185 | Arene         | p-Cymene       | ![p-Cymene](image) | [19]       |
| 186 | Others        | p-Cymen-8-ol   | ![p-Cymen-8-ol](image) | [15]       |
| 187 | Others        | 2-Acetoxy-1,8-cineole | ![2-Acetoxy-1,8-cineole](image) | [17]       |
| 188 | Others        | Diethyl sulphide | ![Diethyl sulphide](image) | [18]       |
| 189 | Others        | Ethyl isopropyl sulphide | ![Ethyl isopropyl sulphide](image) | [18]       |
| 190 | Others        | Methyl allyl sulphide | ![Methyl allyl sulphide](image) | [18]       |
2.3. Diarylheptanoids. Diarylheptanoid is a group of compounds with 1,7-disubstituted phenyl groups and heptane skeletons in its parent structure. Currently, it can be divided into linear diphenyl heptane and cyclic diphenyl heptane compounds with antioxidant activity [53]. The structural formulas are shown in Table 3.

2.4. Others

2.4.1. Proteins and Amino Acids. ZOR contains a variety of amino acids, including glutamate, aspartic acid, serine, glycine, threonine, alanine, cystine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, lysine, histidine, arginine, proline [22, 60], and tryptophan [51].

2.4.2. Sugars. ZOR also contains polysaccharides [44], cellulose, and soluble sugar.

2.4.3. Organic Acids. ZOR contains oxalic acid, tartaric acid, lactic acid, acetic acid, citric acid, succinic acid, formic acid, and malonic acid [61].

2.4.4. Inorganic Elements. ZOR has been shown to contain more than 20 inorganic elements such as K, Mg, Ga, Mn, P, Al, Zn, Fe, and Ba [44].

3. Discussion

Various gingers have different regions and chemical compositions. Jolad [30] conducted quantitative analysis on the extracts of dichloromethane from Chinese white ginger and Japanese turmeric and found that the highest content of 6-gingerol was 28% and 34%, respectively. The next highest concentrations were 8-gingerol and 10-gingerol, and the lowest content of 6-shogaol was only 0.35%. Onyenekwe [62] determined that the main components of the volatile oils of Nigerian ginger were terpenoids such as zingiberene (29.5%) and β-sesquiphellandrene (18.4%), which were quite different from those of ginger grown in other regions. Another study showed the volatile oil content of ginger grown in five different areas of China (Shandong Laiwu, Anhui Tongling, Shandong Anqiu, Guangdong Guangzhou, and Hunan Rucheng) was 0.13%, 0.23%, 0.30%, 0.14%, and 0.17% [63], respectively. 6-Gingerol is often the quality standard for ginger, where the ginger found in Qianwei, Sichuan Province, shows a higher effective content of 6-gingerol than that of the pharmacopoeia standard of the People’s Republic of China [64, 65]. The concentrations of 6-gingerol and 6-zingiberol of ginger grown in different regions of China vary greatly, which may be related to the growth environment [66]. Mature and fresh ginger extracts contain the same chemical components, but the difference is in the relative content of each component. Ginger oleoresin in mature ginger is significantly higher than that in fresh ginger. In aromatic terpenoids, the contents of 2-acetoxy-1,8-cineole, β-citronellal, citral, geraniol, geranyl acetate, and zingiberene in mature ginger are lower than those in fresh ginger. The relative content of α-curcumene in mature ginger was higher than that in fresh ginger. In spicy gingerol compounds, the relative content of gingerol in mature ginger is higher than that in fresh ginger, which may be the result of further synthesis and accumulation of gingerol components in the process of continued growth of mature ginger in the second year [48]. The varieties of ginger with the highest oil content are Laiwu ginger, Japanese ginger, Shannong 1 ginger, Shannong 2 ginger, and Anqiu big ginger, with concentrations of 4.56%, 4.42%, 4.52%, 4.50%, and 4.35%, respectively. Average oil contents of 3.45% and 3.16% were found in Jinchang ginger and Chinger, respectively. The lowest oil extraction rates were found in Anqiu small ginger, Fangzhou ginger, and Jinshi ginger, which were 2.95%, 2.60%, and 1.55%, respectively [48].
| No. | Name                          | Structure | R  | R<sub>1</sub> | R<sub>2</sub> | n  | Reference |
|-----|-------------------------------|-----------|----|--------------|-------------|----|-----------|
| 195 | 3-Gingerol                    | [Image]   | H  | H            | —            | 1  | [30]      |
| 196 | 4-Gingerol                    | [Image]   | H  | H            | —            | 2  | [30]      |
| 197 | 5-Gingerol                    | [Image]   | H  | H            | —            | 3  | [30]      |
| 198 | 6-Gingerol                    | [Image]   | H  | H            | —            | 4  | [31, 32] |
| 199 | 8-Gingerol                    | [Image]   | H  | H            | —            | 6  | [31, 33] |
| 200 | 10-Gingerol                   | [Image]   | H  | H            | —            | 8  | [33]      |
| 201 | 12-Gingerol                   | [Image]   | H  | H            | —            | 10 | [31, 32] |
| 202 | 5-Methoxy-6-gingerol          | [Image]   | H  | CH<sub>3</sub> | —            | 4  | [34]      |
| 203 | Acetoxy-4-gingerol            | [Image]   | H  | COCH<sub>3</sub> | —            | 2  | [34]      |
| 204 | Acetoxy-6-gingerol            | [Image]   | H  | COCH<sub>3</sub> | —            | 4  | [35]      |
| 205 | Acetoxy-8-gingerol            | [Image]   | H  | COCH<sub>3</sub> | —            | 6  | [34]      |
| 206 | Acetoxy-10-gingerol           | [Image]   | H  | COCH<sub>3</sub> | —            | 8  | [34]      |
| 207 | 4-Gingeryl methyl ether       | [Image]   | CH<sub>3</sub> | H            | —            | 2  | [34]      |
| 208 | 6-Gingeryl methyl ether       | [Image]   | CH<sub>3</sub> | H            | —            | 4  | [34]      |
| 209 | 6-Gingeryl methyl ether acetate| [Image] | CH<sub>3</sub> | COCH<sub>3</sub> | —            | 4  | [34]      |
| 210 | 6-Gingeryl diacetate          | [Image]   | COCH<sub>3</sub> | COCH<sub>3</sub> | —            | 4  | [36]      |
| 211 | 8-Gingeryl diacetate          | [Image]   | COCH<sub>3</sub> | COCH<sub>3</sub> | —            | 6  | [36]      |
| 212 | 10-Gingeryl diacetate         | [Image]   | COCH<sub>3</sub> | COCH<sub>3</sub> | —            | 8  | [36]      |
| 213 | Zingerone                     | [Image]   | H  | —            | —            | 0  | [36]      |
| 214 | 1-Paradol                     | [Image]   | H  | —            | —            | 1  | [20]      |
| 215 | 2-Paradol                     | [Image]   | H  | —            | —            | 2  | [20]      |
| 216 | 3-Paradol                     | [Image]   | H  | —            | —            | 3  | [20]      |
| 217 | 4-Paradol                     | [Image]   | H  | —            | —            | 4  | [20]      |
| 218 | 6-Paradol                     | [Image]   | H  | —            | —            | 6  | [36, 37] |
| 219 | 7-Paradol                     | [Image]   | H  | —            | —            | 7  | [20]      |
| 220 | 8-Paradol                     | [Image]   | H  | —            | —            | 8  | [36]      |
| 221 | 9-Paradol                     | [Image]   | H  | —            | —            | 9  | [20]      |
| 222 | 10-Paradol                    | [Image]   | H  | —            | —            | 10 | [36]      |
| 223 | 11-Paradol                    | [Image]   | H  | —            | —            | 11 | [34]      |
| 224 | 13-Paradol                    | [Image]   | H  | —            | —            | 13 | [34]      |
| 225 | Methyl-6-paradol              | [Image]   | CH<sub>3</sub> | —            | —            | 6  | [34, 38] |
| 226 | Methyl-8-paradol              | [Image]   | CH<sub>3</sub> | —            | —            | 8  | [39]      |
| 227 | Zingerone acetate             | [Image]   | COCH<sub>3</sub> | —            | —            | 0  | [36]      |
| 228 | 6-Paradyl monoacetate         | [Image]   | COCH<sub>3</sub> | —            | —            | 6  | [34]      |
| 229 | 8-Paradyl monoacetate         | [Image]   | COCH<sub>3</sub> | —            | —            | 8  | [36]      |
| 230 | 6-Paradyl benzoate            | [Image]   | COPh | —            | —            | 6  | [36]      |
| 231 | 1-Dehydro-3-gingerdione       | [Image]   | —   | —            | —            | 1  | [34]      |
| 232 | 1-Dehydro-6-gingerdione       | [Image]   | —   | —            | —            | 4  | [35, 40] |
| 233 | 1-Dehydro-8-gingerdione       | [Image]   | —   | —            | —            | 6  | [35, 41] |
| 234 | 1-Dehydro-10-gingerdione      | [Image]   | —   | —            | —            | 8  | [37, 42] |
| 235 | 12-Dehydrogingerdione         | [Image]   | —   | —            | —            | 10 | [43]      |
| 236 | 6-Gingerdione                 | [Image]   | —   | —            | —            | 4  | [44]      |
| 237 | 10-Gingerdione                | [Image]   | —   | —            | —            | 8  | [45]      |
| 238 | 4-Shogaol                     | [Image]   | H  | —            | —            | 2  | [30, 44] |
| 239 | 5-Shogaol                     | [Image]   | H  | —            | —            | 3  | [39]      |
| 240 | 6-Shogaol                     | [Image]   | H  | —            | —            | 4  | [35, 37] |
| 241 | 8-Shogaol                     | [Image]   | H  | —            | —            | 6  | [36, 37] |
| 242 | 10-Shogaol                    | [Image]   | H  | —            | —            | 8  | [36, 37] |
| 243 | 12-Shogaol                    | [Image]   | H  | —            | —            | 10 | [30, 44] |
| 244 | Methyl-4-shogaol              | [Image]   | CH<sub>3</sub> | —            | —            | 2  | [39]      |
| 245 | Methyl-6-shogaol              | [Image]   | CH<sub>3</sub> | —            | —            | 4  | [34]      |
| 246 | Methyl-8-shogaol              | [Image]   | CH<sub>3</sub> | —            | —            | 6  | [34]      |
| No. | Name                                           | Structure | R   | R₂   | R₃   | n  | Reference |
|-----|-----------------------------------------------|-----------|-----|------|------|----|-----------|
| 247 | 4-Gingerdiol                                  | H         | H   | H    | H    | 2  | [30]      |
| 248 | 6-Gingerdiol                                  | H         | H   | H    | H    | 4  | [44]      |
| 249 | 8-Gingerdiol                                  | H         | H   | H    | H    | 6  | [44]      |
| 250 | 10-Gingerdiol                                 | H         | H   | H    | H    | 8  | [44]      |
| 251 | 5-Acetoxy-4-gingerdiol                        | H         | COCH₃| H    |      | 2  | [34]      |
| 252 | 5-Acetoxy-6-gingerdiol                        | H         | COCH₃| H    |      | 4  | [46]      |
| 253 | 5-Acetoxy-7-gingerdiol                        | H         | COCH₃| H    |      | 5  | [34]      |
| 254 | Diacetoxy-4-gingerdiol                        | H         | COCH₃| COCH₃|      | 2  | [46, 47]  |
| 255 | Diacetoxy-6-gingerdiol                        | H         | COCH₃| COCH₃|      | 4  | [46, 47]  |
| 256 | Methyl-5-acetoxy-4-gingerdiol                 | CH₃       | COCH₃| H    |      | 2  | [34]      |
| 257 | Methyl-5-acetoxy-6-gingerdiol                 | CH₃       | COCH₃| H    |      | 4  | [34]      |
| 258 | Methyl diacetoxy-4-gingerdiol                 | CH₃       | COCH₃| COCH₃|      | 2  | [34]      |
| 259 | Methyl diacetoxy-6-gingerdiol                 | CH₃       | COCH₃| COCH₃|      | 4  | [34]      |
| 260 | Methyl diacetoxy-10-gingerdiol                | CH₃       | COCH₃| COCH₃|      | 8  | [34]      |
| 261 | 6-Dihydroparadol                              | Ac        | —   | —    | —    | 6  | [34]      |
| 262 | Acetoxy-6-dihydroparadol                      | H         | —   | —    | —    | —  | [34]      |
| 263 | 1-(4'-Hydroxy-3'-methoxyphenyl)-7-octen-3-one| H         | —   | —    | —    | —  | [34]      |
| 264 | 1-(4'-Hydroxy-3'-methoxyphenyl)-7-decen-3-one | H         | —   | —    | —    | —  | [34]      |
| 265 | 1-(4'-Hydroxy-3'-methoxyphenyl)-7-dodecen-3-one | H         | —   | —    | —    | —  | [34]      |
| 266 | 4-Isogingerol                                 | H         | —   | —    | —    | 2  | [34]      |
| 267 | 6-Isogingerol                                 | H         | —   | —    | —    | 4  | [48]      |
| 268 | Methyl-6-isogingerol                          | CH₃       | —   | —    | —    | 4  | [34]      |
| 269 | 6-Zingerine                                   | —         | —   | —    | —    | 4  | [49]      |
| 270 | 8-Zingerine                                   | —         | —   | —    | —    | 6  | [49]      |
| 271 | 10-Zingerine                                  | —         | —   | —    | —    | 8  | [49]      |
| 272 | 3-Dihydro-6-demethoxy shogaol                 | —         | —   | —    | —    | —  | [34]      |
| 273 | 6-Isoshogaol                                  | —         | —   | —    | —    | —  | [44]      |
| 274 | Dehydrozingerone                              | —         | —   | —    | —    | —  | [36]      |
Ginger, as a kind of food and medicine, has many functions, such as antioxidant, anti-inflammatory, antimicrobial, anticancer, antiobesity, antidiabetic, antinausea, antiemetic, neuroprotective, hepatoprotective, cardiovascular protective, and respiratory protective activities [67]. Currently, most studies of the bioactive components of ginger focus on ginger volatile oil, gingerol, shogaol, and zingerone compounds. Ginger essential oil can effectively improve the antioxidant capacity of the liver, reduce inflammatory response, and protect against fatty liver [68]. The antioxidant compounds in ginger are primarily gingerol and diarylheptanoids. Substituents on alkyl chains contribute to free radical scavenging and oxidation inhibition of lipids [69]. Antioxidant activity is typically derived from gingerols, shogaols, and some related phenolic ketone derivatives [70]. Gingerols are spicy ingredients in which 6-gingerol shows the highest biological activity, so 6-gingerol is often used as an indicator of ginger quality [71]. 6-Gingerol has been used to inhibit angiogenesis in vivo and in vitro [72]. It has been shown to have anticancer and antigastric ulcer properties while suppressing central nervous stimulation and various pharmacological activities [73, 74]. 6-Gingerol has been used to treat tumors by regulating the apoptosis gene by reversing the abnormal expression of tumor cell genes. It can also affect the apoptosis signal transduction pathway and induce apoptosis [75]. 8-Gingerol and 10-gingerol have good inhibitory effects on the activity of various tumor cells, where the inhibitory effects are somewhat different. The two may affect the phosphorylation level of the MAPK pathway proteins ERK and P38, leading to G1 phase arrest of breast cancer cells, thus applying inhibitory effects on the proliferation of tumor cells [76]. The main components of strong heart are gingerol and 6-shogaol [77]. The effects of 6-gingerol and 6-shogaol on blood pressure have been shown to induce a hypotensive effect at low doses, while high doses have shown a three-phase reaction. Initially, blood pressure drops rapidly, then rises, and then provides a hypotensive effect at later stages [78]. Ginger polysaccharide has biological activities such as antitumor, hypoglycemic, lipid-lowering, immune regulation, antiviral, and antifatigue [79].

4. Conclusion

ZOR is a widely used drug and food in clinical and daily life and has been used in the prevention and treatment of the digestive, circulatory, respiratory, and central nervous system diseases and other diseases. In this paper, the chemical constituents found in ZOR in recent years are summarized, and the results show that more than 300 chemical constituents are identified from the extracts of ZOR, including 194 types of volatile oil, 85 types of gingerol, and 28 types of diarylheptanoids compounds. From this, it can be clearly observed that ZOR has a complex chemical composition. The interactions between the components provide the clinical effects; therefore, it is necessary to further study the chemical composition and pharmacological action of ginger, for further applications. Exploring the mechanism by which different components perform the same effects is a new way to develop drugs in the future; for example, 4-terpineol and beta-sitosterol can act on the two targets of the 5-
| No. | Name | Structure | R₁ | R₂ | R₃ | Reference |
|-----|------|-----------|----|----|----|-----------|
| 280 | 5-Hydroxy-1-(4’-hydroxy-3’-methoxyphenyl)-7-(4’-hydroxyphenyl)heptan-3-one | | H | H | H | [32] |
| 281 | 5-Hydroxy-1,7-bis(4’-hydroxy-3’-methoxyphenyl)heptan-3-one | | | | | |
| 282 | 7-(3’,4’-Di hydroxy-5’-methoxyphenyl)-5-hydroxy-1-(4”-hydroxy-3”-methoxyphenyl)heptan-3-one | | H | OCH₃ | H | [32] |
| 283 | 5-Hydroxy-7-(4’-hydroxy-3’,5’-dimethoxyphenyl)-1-(4”-hydroxy-3”-methoxyphenyl)heptan-3-one | | H | OCH₃ | OCH₃ | [32] |
| 284 | 5-Hydroxy-1-(4’-hydroxy-3’,5’-dimethoxyphenyl)-7-(4”-hydroxy-3”-methoxyphenyl)heptan-3-one | | | | | |
| 285 | (E)-7-(3’,4’-Dihydroxyphenyl)-1-(4”-hydroxy-3”-methoxyphenyl)hept-4-en-3-one | | H | — | V | [55] |
| 286 | 1,7-bis(4’-Hydroxy-3’-methoxyphenyl)-4-heptene-3-one | | CH₃ | — | — | [54–56] |
| 287 | 3,5-Dihydroxy-1,7-bis(4’-hydroxy-3’-methoxyphenyl)heptan-3-one | | H | H | CH₃ | [54–56] |
| 288 | 1,7-bis(4’-Hydroxy-3’-methoxyphenyl)-3,5-diacetateheptane | | COCH₃ | H | CH₃ | [55] |
| 289 | 1,7-bis(3’,4’-Diacetatephenyl)-3,5-diacetateheptane | | COCH₃ | CH₃ | COCH₃ | [55] |
| 290 | 1,7-bis(3’,4’-Diacetatephenyl)-3,5-diacetateheptane | | COCH₃ | CH₃ | COCH₃ | [55] |
| 291 | 1,7-bis(3’,4’-Diacetatephenyl)-3,5-diacetateheptane | | COCH₃ | COCH₃ | COCH₃ | [55] |
| 292 | 5-(6-(4-Hydroxy-3-methoxyphenethyl)-4-hydroxy-tetrahydro-2H-pyran-2-yl)-3-methoxybenzene-1,2-diol | | H | — | — | [54, 58] |
| 293 | 2-(4’-Hydroxy-3’-methoxyphenethyl)-6-(3”,4”-dihydroxy-5”-methoxyphenyl)tetrahydro-2H-pyran-4-yl acetate | | | | | |
| 294 | 7-(3’,4’-Dihydroxyphenyl)-1-(4”-hydroxy-3”-methoxyphenyl)-3,5-diacetateheptane | | H | H | | [55] |
| 295 | 7-(4’-Hydroxy-3’-methoxyphenyl)-1-(4”,5”-dihydroxy-3”-methoxyphenyl)-3,5-diacetateheptane | | | | | |
| 296 | 7-(4’-Hydroxy-3’-methoxyphenyl)-1-(4”-hydroxy-5”-methyl-3”-methoxyphenyl)-3,5-diacetateheptane | | | | | |
| 297 | 7-(4’-Hydroxy-3’-methoxyphenyl)-1-(4”-hydroxy-5”-methyl-3”-methoxyphenyl)-3,5-diacetateheptane | | | | | |
| 298 | 7-(4’-Hydroxy-3’-methoxyphenyl)-1-(4”-hydroxy-3”-5”-dimethoxyphenyl)-3,5-diacetateheptane | | | | | |
| 299 | 5-(6-(4-Hydroxyphenethyl)-4-hydroxy-tetrahydro-2H-pyran-2-yl)-3-methoxybenzene-1,2-diol | | H | H | H | [25] |
| 300 | 5-(6-(4-Hydroxy-3-methoxyphenethyl)-4-hydroxy-tetrahydro-2H-pyran-2-yl)-3-methoxybenzene-1,2-diol | | H | H | OCH₃ | [54, 58] |
| 301 | 5-(6-(4-Hydroxy-3-methoxyphenethyl)-4-hydroxy-tetrahydro-2H-pyran-2-yl)-2-hydroxy-3-methoxyphenyl acetate | | H | COCH₃ | OCH₃ | [58] |
| 302 | 2-(4’-Hydroxy-3’-methoxyphenethyl)-6-(3”,4”-dihydroxy-5”-methoxyphenyl)tetrahydro-2H-pyran-4-yl acetate | | COCH₃ | H | OCH₃ | [58] |
| 303 | 1,7-bis(4’-Hydroxy-3’-methoxyphenyl)-5-oxoheptan-3-yl acetate | | H | — | — | [57] |
| 304 | 1,7-bis(3’-Methoxy-4’-acetatephenyl)-5-oxoheptan-3-yl acetate | | COCH₃ | — | — | [57] |
hydroxytryptamine receptor 3A and the mu-type opioid receptor, respectively, and provide corresponding therapeutic effects on diarrhea and dysentery. This can provide ideas for the research and development of new drugs and lay a foundation for further applications of ZOR.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Table 3: Continued.

| No. | Name | Structure | R1 | R2 | R3 | Reference |
|-----|------|-----------|----|----|----|-----------|
| 305 | 1,7-bis(4’-Hydroxy-3’-methoxyphenyl)-3,5-heptadione | ![Structure](image) | — | — | — | [34] |
| 306 | (1E,6E)-1,7-bis(4-Hydroxy-3-methoxyphenyl)hepta-1,6-diene-3,5-dione | ![Structure](image) | — | — | — | [56] |
| 307 | 2,4-bis(3,4-Dihydroxyphenethyl)pentanedioic acid | ![Structure](image) | — | — | — | [59] |
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