High-protein oat groats were defatted once (1X) or three times (3X) and air-classified. The protein contents of the 1X and 3X defatted materials were 3.4 and 23.5%, respectively; the combined high-protein fine fractions from air classification had protein contents of 30.1 and 32.7%. These fractions accounted for 21% and 24% of the weight (and for 27% and 33% of the total protein) of the 1X and 3X defatted groats, respectively. The coarse residue fraction (>30 μm) from air classification of 1X and 3X defatted groats had β-glucan contents of 16.9 and 17.7%, respectively, compared with 6.1-6.2% in the original defatted groats. These coarse residue fractions accounted for 30% and 28% weight and 82% of total β-glucan of the 1X and 3X defatted groats, respectively. Useful protein shifting was 25% for the 1X and 30% for the 3X defatted groats. Useful β-glucan shifting was 104% for the 1X and 107% for the 3X defatted groats. Air classification of high-protein oat groats may have commercial potential for producing protein concentrate and enriched β-glucan fraction in a single process.

Oats have a relatively high protein content with good nutritional quality when compared to other cereal grains (Jones et al 1948, Hirschke et al 1968, Robbins et al 1971). Most cereal grains are deficient in lysine, and the weight of lysine may decrease as protein content increases (Frey 1951, Vavilich et al 1959, Munck et al 1970). In oats, amino acid balance is maintained as protein content is increased (Robbins et al 1971, Maruyama et al 1975).

There is a strong positive correlation between blood cholesterol levels and the risk of heart disease (American Heart Association 1986). A number of investigators have shown that consumption of soluble dietary fiber can lower serum cholesterol in humans (Anderson and Chen 1979; Chen et al 1981, 1984; Kritchevsky et al 1984; Judd and Truswell 1985; Van Horn et al 1986). Oats contain soluble fiber, a major component of which is β-glucan.

Knuckles et al (1992) used grinding and sieving to enrich β-glucan content from barley, rolled oats, and oat bran. Hohner and Hyldon (1977) used a wet process to obtain protein, starch, and gum fractions from oat groats. Wood et al (1989) similarly extracted a β-glucan-rich oat gum from oat bran using sodium carbonate at pH 10. Wu and Stringfellow (1973) reported the air classification of oat flours of normal and high-protein contents and found that the fine fraction had increased protein content. Wu et al (1994) reported that air classification of barley flour concentrated the β-glucan in the coarse fraction. Thus, it appeared reasonable that air classification of a high-protein oat flour might produce protein concentrate from fine fractions and an enriched β-glucan fraction from the coarse residue. A process that produces both a protein concentrate and an enriched β-glucan fraction may have advantages over a process giving either product alone. This article describes the enrichment of protein and β-glucan fractions from air classification of partially defatted oat groats from a cultivar with high protein content.

MATERIALS AND METHODS

Preparation of Defatted Oat Groats

Otee oats, lot number WM-DM-2, (23.5% protein, db) are high-protein spring oats developed cooperatively by the Illinois Agricul-
shifted into the high-protein fractions and out of the low-protein
fractions as a percentage of the total protein present in the starting
material (Gracza 1959). Useful ,B-glucan shifting can be defined
for 2B and 3B. Fractions IB and 5B had higher protein
content than the groats, and fractions 3B and 4B were lower
in protein. Although the fractions IB and 5B had similar high­
protein contents, they were not identical. Fraction 1B had very
fine soft particles and was considerably lower in both ash and
fat as compared to the coarse hard particles in fraction 5B. The
largest fraction by weight was fraction 5B, which accounted for
almost a third of the groats weight. It is unusual to find an increase
in protein for coarse residue, although similar results were ob­
served with fractionated sorghum flour (Stringfellow and
Peplinski 1966). For wheat flour, coarse residue protein value
approaches that of the starting flour (Peplinski et al 1964,
Stringfellow and Peplinski 1964,). Fractions 1A and 2A-5A, ultra­
fine material collected in low yield from the exhaust air bag,
had 80–81% protein. ,B­Glucan contents increased with increasing
particle size from fractions 1B to 5B, and there was a large increase
in ,B-glucan content between fractions 4B and 5B. Fraction 5B
had higher ash and fat contents than the 1X defatted groats,
but other fractions had lower ash and fat contents.

The air-classified fractions from 3X defatted groats (Table I)
followed the same general pattern as the 1X defatted groats. However, fractions from the lower fat groats gave lower protein
content for fractions 2B-3B. ,B­Glucan content of fractions 4B
and 5B were higher than the corresponding fractions from 1X
defatted groats.

Combined high-protein fractions of both the 1X and 3X defatted
groats are compared with the coarse high ,B-glucan fraction in
Table II. The combined high-protein fine fractions from 1X
defatted groats had a protein content of 32.5% and accounted
for 21% of the groats weight and 27% of the total protein. The
corresponding combined high-protein fine fractions from 3X
defatted groats had a protein content of 32.5% and accounted
for 24% of the weight and 33% of the total protein.

The coarse residue fractions had higher protein contents than
the groats and accounted for 28 and 30% of the weight and 34–36% of the total protein of the groats (Table II). The coarse residue
fraction had much higher ,B-glucan contents than the groats
(16.9–17.7% vs. 6.1–6.2%) and accounted for 82% of the total
,B-glucan of the groats. The yield, amount of total initial protein, and amount of total 
,B-glucan of the combined fractions 2B, 3B, and 4B (not included in Table II because they were lower in both protein and 
,B-glucan than the starting material) can be readily obtained by subtracting
the sum of combined high-protein fine fractions 1A, 2A-5A, 1B,
and coarse residue fraction 5B from 100%.

**Useful Protein Shifting and ,B­Glucan Shifting**

Useful protein shifting of 1X defatted groats was 25%. The 3X
defatted groats had an useful protein shifting of 30% (Table II).
For comparison, the useful protein shifting of Garland defatted
groats with 1.4% fat was 37% (Wu and Stringfellow 1973).

When material with 10% initial ,B-glucan content was separated
by air classification into fraction 1 with 33.3% yield and 30% of
,B-glucan content and fraction 2 with 66.7% yield and zero
,B-glucan content, the ,B-glucan shifting was 133%. A useful ,B­
glucan shifting value of more than 100% is thus possible. Our
useful ,B-glucan shifting values of 104 and 107% in Table II showed
that air classification of defatted Otee groats was an excellent
method to yield enriched ,B-glucan fraction.

**Amino Acid Composition**

Combined high-protein fine fractions 1A, 2A-5A, 1B, (21–24% yield of defatted groats) may have potential as a protein

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**TABLE I**

Air Classification of Defatted Otee Groats (% db)

<table>
<thead>
<tr>
<th>Fractions</th>
<th>1X Defatted</th>
<th>3X Defatted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A, exhaust bag</td>
<td>Yield 1</td>
<td>Starch (N × 6.25) 80.1 A3</td>
</tr>
<tr>
<td>2A-5A, exhaust bag</td>
<td>20 58.2 B</td>
<td>27.7 D</td>
</tr>
<tr>
<td>1B</td>
<td>14 66.5 A</td>
<td>22.0 E</td>
</tr>
<tr>
<td>3B</td>
<td>26 67.4 A</td>
<td>16.1 G</td>
</tr>
<tr>
<td>4B</td>
<td>9 57.4 B</td>
<td>14.5 H</td>
</tr>
<tr>
<td>5B, coarse residue</td>
<td>30 14.8 C</td>
<td>28.1 D</td>
</tr>
<tr>
<td>Groats</td>
<td>23.4 E</td>
<td>6.2 C</td>
</tr>
</tbody>
</table>

**Results and Discussion**

**Air Classification**

Yield, starch, protein, ,B-glucan, fat, and ash contents of 1X
and 3X defatted Otee groats after air classification are given in
Table I. Yield data for each fraction was rounded off to the
nearest percent. Otee groats had 7.8% fat (db) (not shown in
Table I). More than 50% of this fat was removed by defatting
once with hexane.

The 1X defatted groats had 23.4% protein. Fraction 3B had
the highest starch content (67%) among the five major fractions
1B through 5B, and fraction 5B had the lowest starch content
(15%). Fractions 1B and 4B had lower starch content than
fractions 2B and 3B. Fractions 1B and 5B had higher protein
content than the groats, and fractions 3B and 4B were lower
in protein. Although the fractions 1B and 5B had similar high­
protein contents, they were not identical. Fraction 1B had very
fine soft particles and was considerably lower in both ash and
fat as compared to the coarse hard particles in fraction 5B. The
largest fraction by weight was fraction 5B, which accounted for
almost a third of the groats weight. It is unusual to find an increase
in protein for coarse residue, although similar results were ob­
served with fractionated sorghum flour (Stringfellow and

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**TABLE II**

Comparison of Air-Classification Response
of Defatted Otee Groats (% db)

<table>
<thead>
<tr>
<th>Fractions</th>
<th>1X Defatted</th>
<th>3X Defatted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting material</td>
<td>Yield 100</td>
<td>100</td>
</tr>
<tr>
<td>Protein content</td>
<td>23.4</td>
<td>23.5</td>
</tr>
<tr>
<td>β-Glucan content</td>
<td>6.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Combined high-protein fine fractions 1A, 2A-5A, 1B</td>
<td>Yield 21</td>
<td>24</td>
</tr>
<tr>
<td>Protein content</td>
<td>30.2</td>
<td>32.5</td>
</tr>
<tr>
<td>Amount of total initial protein</td>
<td>27</td>
<td>33</td>
</tr>
<tr>
<td>Coarse residue fraction 5B</td>
<td>Yield 30</td>
<td>28</td>
</tr>
<tr>
<td>Protein content</td>
<td>28.1</td>
<td>28.2</td>
</tr>
<tr>
<td>β-Glucan content</td>
<td>16.9</td>
<td>17.7</td>
</tr>
<tr>
<td>Amount of total initial protein</td>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td>Amount of total β-glucan</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>Useful protein shifting</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Useful β-glucan shifting</td>
<td>104</td>
<td>107</td>
</tr>
</tbody>
</table>
concentrate in human food. To evaluate the nutritional value of these fractions, the essential amino acid composition of 3X defatted Otee groats and air-classified fractions are compared with the recommended amino acid pattern (WHO 1985) for preschool child (2-5 years) and a school child (10-12 years) in Table III. The essential amino acid composition of 1X defatted Otee groats and air-classified fractions were very similar to 3X and are not shown. The air-classified fractions had very similar amino acid composition when compared with the groats. Although Otee groats had much higher lysine content than most cereals, they were still deficient in lysine when compared with the WHO recommendation for a preschool child, although adequate for school age child. Other essential amino acids of these fractions, however, met or exceeded the WHO recommendation for children.

**TABLE III**

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Groats</th>
<th>1A Exhaust Bag</th>
<th>2A-5A Exhaust Bag</th>
<th>5B Coarse Residue</th>
<th>Recommendations for Children*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Exhaust Bag</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-5 yr</td>
<td>10-12 yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoleucine</td>
<td>4.1</td>
<td>4.0</td>
<td>4.7</td>
<td>4.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Leucine</td>
<td>7.8</td>
<td>7.4</td>
<td>8.4</td>
<td>7.8</td>
<td>7.5</td>
</tr>
<tr>
<td>Lysine</td>
<td>4.1</td>
<td>3.9</td>
<td>4.4</td>
<td>4.1</td>
<td>4.6</td>
</tr>
<tr>
<td>Methionine + cystine</td>
<td>3.3</td>
<td>3.7</td>
<td>3.5</td>
<td>3.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Phenylalanine + tyrosine</td>
<td>10.6</td>
<td>10.9</td>
<td>10.9</td>
<td>10.2</td>
<td>9.5</td>
</tr>
<tr>
<td>Threonine</td>
<td>3.4</td>
<td>3.3</td>
<td>3.1</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>1.3*</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Valine</td>
<td>5.5</td>
<td>5.5</td>
<td>5.4</td>
<td>5.7</td>
<td>5.6</td>
</tr>
</tbody>
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**ACKNOWLEDGMENT**

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**LITERATURE CITED**


