In [1]:
```
import tensorflow as tf
from tensorflow.keras import regularizers
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow import keras
from keras import layers
from keras import models
from tensorflow.keras import optimizers
from sklearn.metrics import classification_report
import numpy as np
```

```
2025-06-11 17:29:49.198610: E external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:467] Unable to register cuFFT factory: Attempting to register factory for plugin cuFFT when one has already been registered
WARNING: All log messages before absl::InitializeLog() is called are written to STDERR
E0000 00:00:1749659389.212524 3250193 cuda_dnn.cc:8579] Unable to register cuDNN factory: Attempting to register factory for plugin cuDNN when one has already been registered
E0000 00:00:1749659389.216758 3250193 cuda_blas.cc:1407] Unable to register cuBLAS factory: Attempting to register factory for plugin cuBLAS when one has already been registered
W0000 00:00:1749659389.227353 3250193 computation_placer.cc:177] computation placer already registered. Please check linkage and avoid linking the same target more than once.
W0000 00:00:1749659389.227370 3250193 computation_placer.cc:177] computation placer already registered. Please check linkage and avoid linking the same target more than once.
W0000 00:00:1749659389.227371 3250193 computation_placer.cc:177] computation placer already registered. Please check linkage and avoid linking the same target more than once.
W0000 00:00:1749659389.227372 3250193 computation_placer.cc:177] computation placer already registered. Please check linkage and avoid linking the same target more than once.
2025-06-11 17:29:49.231291: I tensorflow/core/platform/cpu_feature_guard.cc:210] This TensorFlow binary is optimized to use available CPU instructions in performance-critical operations.
To enable the following instructions: AVX2 FMA, in other operations, rebuild TensorFlow with the appropriate compiler flags.
```

In [2]:
```
tf.__version__
```

Out[2]:
```
'2.19.0'
```

MODELO S

1 - Data Preprocessing

Caminhos dos sets

In [3]:
```
train_dir = 'dataset_balanceado_final/train'
validation_dir = 'dataset_balanceado_final/validation'
test_dir = 'dataset_balanceado_final/test'
```

Definir batch_size e image_size

In [4]:
```
from tensorflow.keras.utils import image_dataset_from_directory

IMG_SIZE = 150
BATCH_SIZE = 32
```

Training set - É o conjunto de dados usado para treinar a rede

In [5]:
```
train_dataset = image_dataset_from_directory(
    train_dir,
    image_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE,
    label_mode='categorical' # categorical porque temos várias classes, senão se
)
```

```
Found 4276 files belonging to 7 classes.
I0000 00:00:1749659391.667528 3250193 gpu_device.cc:2019] Created device /job:loc
alhost/replica:0/task:0/device:GPU:0 with 4804 MB memory:  -> device: 0, name: NV
IDIA GeForce GTX 1660 SUPER, pci bus id: 0000:03:00.0, compute capability: 7.5
I0000 00:00:1749659391.671027 3250193 gpu_device.cc:2019] Created device /job:loc
alhost/replica:0/task:0/device:GPU:1 with 4804 MB memory:  -> device: 1, name: NV
IDIA GeForce GTX 1660 SUPER, pci bus id: 0000:05:00.0, compute capability: 7.5
```

Validation set - Usado para 'testar' o modelo durante o processo de procura da melhor combinação de hiperparâmetros.

In [6]:
```
validation_dataset = image_dataset_from_directory(
    validation_dir,
    image_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE,
    label_mode='categorical'
)
```

```
Found 1420 files belonging to 7 classes.
```

Test set - Usado para testar o modelo depois do processo de treino

In [7]:
```
test_dataset = image_dataset_from_directory(
    test_dir,
    image_size=(IMG_SIZE, IMG_SIZE),
    batch_size=BATCH_SIZE,
    label_mode='categorical'
)
```

```
Found 1420 files belonging to 7 classes.
```

Métricas para avaliar os modelos

In [8]:
```
# Utiliza uma função(do sckicit-learn) para avaliar o desempenho do modelo, indi
    # f1-score do modelo
    # accuracy do modelo
    # accuracy por classe

from sklearn.metrics import classification_report
import numpy as np
```

```
def print_classification_metrics(model, dataset, phase_name):
    y_true = []
    y_pred = []

    for images, labels in dataset:
        preds = model.predict(images)
        y_true.extend(np.argmax(labels.numpy(), axis=1))
        y_pred.extend(np.argmax(preds, axis=1))

    print(f"\n {phase_name}")
    print(classification_report(y_true, y_pred, digits=4))
```

2 - Construir a CNN (convolucional Neural Network)

In [9]:
```
# Define a camada de entrada do modelo com o formato das imagens (altura, largur
inputs = keras.Input(shape=(IMG_SIZE, IMG_SIZE, 3))
```

In [10]:
```
# Normaliza os valores dos pixels das imagens de entrada para o intervalo [0, 1]
x = layers.Rescaling(1./255)(inputs)
```

Passo 1 : Camada Convolucional

In [11]:
```
# Primeira camada convolucional com 64 filtros 3x3 e ativação ReLU
x = layers.Conv2D(filters=64, kernel_size=3, activation="relu", padding="same")(
# adicionado o padding="same" para garantir que o output da camada convolucional
```

Passo 2 : Camada de Pooling

In [12]:
```
# Primeira camada de pooling máximo (2x2) para reduzir a dimensionalidade.
x = layers.MaxPooling2D(pool_size=2)(x)
```

Passo 3 : Adicionar mais camadas

In [13]:
```
# Segunda camada convolucional com 128 filtros 3x3 e ativação ReLU.
x = layers.Conv2D(filters=128, kernel_size=3, activation="relu", padding="same")
# Segunda camada de pooling máximo (2x2).
x = layers.MaxPooling2D(pool_size=2)(x)
```

In [14]:
```
# Terceira camada convolucional com 128 filtros 3x3 e ativação ReLU.
x = layers.Conv2D(filters=128, kernel_size=3, activation="relu", padding="same")
# Terceira camada de pooling máximo (2x2).
x = layers.MaxPooling2D(pool_size=2)(x)
```

Passo 4 : Flattening

In [15]:
```
# Achata o output das camadas convolucionais para um vetor 1D.
x = layers.Flatten()(x)
```

BATCH NORMALIZATION (Facultativo)

In [16]:
```
# tirar comentario desta linha abaixo se queremos usar batch normalization
# porem foi testado varias vezes e em diferentes camadas da rede, mas não melhor
#x = layers.BatchNormalization( axis=-1, momentum=0.99, epsilon=0.001, center=Tr
```

Dropout (facultativo) - funçao de regularização

In [17]:
```
# Aplica Dropout (50%) para desativar aleatoriamente neurónios, prevenindo o ove
x = layers.Dropout(0.5)(x)
```

Passo 5 : Full Connection

In [18]:
```
# Definir funçao de Regularização L2 (opcional)
reg = regularizers.l2(0.01)  # Executar para ativar

# Camada densa (totalmente conectada) com 128 neurónios, ativação ReLU e funçao
x = layers.Dense(128, activation="relu", kernel_regularizer=reg)(x)
```

Passo 6 : Output Layer

In [19]:
```
# Camada de saída densa com 7 neurónios e ativação Softmax (para classificação c
outputs = layers.Dense(7, activation="softmax")(x)
```

In [20]:
```
# Cria o modelo Keras usando as camadas de entrada e saída definidas.
model = keras.Model(inputs=inputs, outputs=outputs)
```

3 - Treinar a rede CNN

Funções de otimização disponíveis: Adam, RMSprop e SGD

Funções de loss disponíveis: categorical_crossentropy , KLDivergence e MSE

In [21]:
```
# Configura o otimizador Adam
# Define a função de loss: Categorical crossentropy
# Indica que a 'accuracy' (precisão) será a métrica durante o treino.
model.compile(
    optimizer=tf.keras.optimizers.Adam(),
    loss=tf.keras.losses.CategoricalCrossentropy(),
    metrics=['accuracy'])
```

In [22]:
```
#model.compile(
    #optimizer='SGD',
    #loss='mse',
    #metrics=['accuracy'])
```

In [23]:
```
#model.compile(
    #optimizer=tf.keras.optimizers.RMSprop(),
    #loss=tf.keras.losses.KLDivergence(),
    #metrics=['accuracy'])
```

Treinar o modelo

In [24]:
```
history = model.fit(
    train_dataset, #Inicia o treino do modelo usando o conjunto de dados de trei
    epochs=25,     # O modelo será treinado por 25 épocas (passagens completas p
    validation_data=validation_dataset) # Usa o conjunto de dados de validação p
```

```
Epoch 1/25
WARNING: All log messages before absl::InitializeLog() is called are written to S
TDERR
I0000 00:00:1749659394.358268 3250257 service.cc:152] XLA service 0x7d6ee8007b40
initialized for platform CUDA (this does not guarantee that XLA will be used). De
vices:
I0000 00:00:1749659394.358289 3250257 service.cc:160]   StreamExecutor device
(0): NVIDIA GeForce GTX 1660 SUPER, Compute Capability 7.5
I0000 00:00:1749659394.358293 3250257 service.cc:160]   StreamExecutor device
(1): NVIDIA GeForce GTX 1660 SUPER, Compute Capability 7.5
2025-06-11 17:29:54.391709: I tensorflow/compiler/mlir/tensorflow/utils/dump_mlir
_util.cc:269] disabling MLIR crash reproducer, set env var `MLIR_CRASH_REPRODUCER
_DIRECTORY` to enable.
I0000 00:00:1749659394.568763 3250257 cuda_dnn.cc:529] Loaded cuDNN version 90300
2025-06-11 17:29:54.906468: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.9 = (f32[32,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,3,150,150]{3,2,1,0} %bitcast.4962, f32[64,3,3,3]{3,2,1,0} %bitcast.47
50, f32[64]{0} %bitcast.5305), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi0
1->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_typ
e="Conv2D" op_name="functional_1/conv2d_1/convolution" source_file="/home/eliana/
escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py" sour
ce_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queue
s":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kNon
e","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:29:55.006744: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.10 = (f32[32,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,64,75,75]{3,2,1,0} %bitcast.5373, f32[128,64,3,3]{3,2,1,0} %bitcast.4
771, f32[128]{0} %bitcast.5433), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_o
i01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_t
ype="Conv2D" op_name="functional_1/conv2d_1_2/convolution" source_file="/home/eli
ana/escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py"
source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_qu
eues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kN
one","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:29:55.412336: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.11 = (f32[32,128,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,128,37,37]{3,2,1,0} %bitcast.5497, f32[128,128,3,3]{3,2,1,0} %bitcas
t.4790, f32[128]{0} %bitcast.5557), window={size=3x3 pad=1_1x1_1}, dim_labels=bf0
1_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={o
p_type="Conv2D" op_name="functional_1/conv2d_2_1/convolution" source_file="/home/
eliana/escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.p
y" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation
_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mod
e":"kNone","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":fa
lse}
  3/134 ━━━━━━━━━━━━━━━━━━━━ 8s 66ms/step - accuracy: 0.1406 - loss: 4.5533
I0000 00:00:1749659398.514552 3250257 device_compiler.h:188] Compiled cluster usi
ng XLA!  This line is logged at most once for the lifetime of the process.
133/134 ━━━━━━━━━━━━━━━━━━━━ 0s 64ms/step - accuracy: 0.2006 - loss: 2.6475
```

```
2025-06-11 17:30:07.387108: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.9 = (f32[20,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[20,3,150,150]{3,2,1,0} %bitcast.4962, f32[64,3,3,3]{3,2,1,0} %bitcast.47
50, f32[64]{0} %bitcast.5305), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi0
1->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_typ
e="Conv2D" op_name="functional_1/conv2d_1/convolution" source_file="/home/eliana/
escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py" sour
ce_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queue
s":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kNon
e","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:30:07.479720: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.10 = (f32[20,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[20,64,75,75]{3,2,1,0} %bitcast.5373, f32[128,64,3,3]{3,2,1,0} %bitcast.4
771, f32[128]{0} %bitcast.5433), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_o
i01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_t
ype="Conv2D" op_name="functional_1/conv2d_1_2/convolution" source_file="/home/eli
ana/escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py"
source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_qu
eues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kN
one","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:30:07.761092: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.11 = (f32[20,128,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[20,128,37,37]{3,2,1,0} %bitcast.5497, f32[128,128,3,3]{3,2,1,0} %bitcas
t.4790, f32[128]{0} %bitcast.5557), window={size=3x3 pad=1_1x1_1}, dim_labels=bf0
1_oi01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={o
p_type="Conv2D" op_name="functional_1/conv2d_2_1/convolution" source_file="/home/
eliana/escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.p
y" source_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation
_queues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mod
e":"kNone","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":fa
lse}
```

134/134 ━━━━━━━━━━━━━━━━━━━━ **0s** 89ms/step - accuracy: 0.2009 - loss: 2.6440

```
2025-06-11 17:30:10.679415: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.9 = (f32[32,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,3,150,150]{3,2,1,0} %bitcast.572, f32[64,3,3,3]{3,2,1,0} %bitcast.57
9, f32[64]{0} %bitcast.581), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01-
>bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type
="Conv2D" op_name="functional_1/conv2d_1/convolution" source_file="/home/eliana/e
scola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py" sourc
e_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queue
s":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRel
u","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:30:10.762703: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.10 = (f32[32,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,64,75,75]{3,2,1,0} %bitcast.589, f32[128,64,3,3]{3,2,1,0} %bitcast.59
6, f32[128]{0} %bitcast.598), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01
->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type
="Conv2D" op_name="functional_1/conv2d_1_2/convolution" source_file="/home/elian
a/escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py" so
urce_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queu
es":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRel
u","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:30:11.167248: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.11 = (f32[32,128,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[32,128,37,37]{3,2,1,0} %bitcast.604, f32[128,128,3,3]{3,2,1,0} %bitcast.
611, f32[128]{0} %bitcast.613), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi
01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_ty
pe="Conv2D" op_name="functional_1/conv2d_2_1/convolution" source_file="/home/elia
na/escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py" s
ource_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_que
ues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRe
lu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:30:13.267375: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.9 = (f32[12,64,150,150]{3,2,1,0}, u8[0]{0}) custom-
call(f32[12,3,150,150]{3,2,1,0} %bitcast.572, f32[64,3,3,3]{3,2,1,0} %bitcast.57
9, f32[64]{0} %bitcast.581), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01-
>bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type
="Conv2D" op_name="functional_1/conv2d_1/convolution" source_file="/home/eliana/e
scola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py" sourc
e_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queue
s":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRel
u","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:30:13.323926: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.10 = (f32[12,128,75,75]{3,2,1,0}, u8[0]{0}) custom-
call(f32[12,64,75,75]{3,2,1,0} %bitcast.589, f32[128,64,3,3]{3,2,1,0} %bitcast.59
6, f32[128]{0} %bitcast.598), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi01
->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_type
="Conv2D" op_name="functional_1/conv2d_1_2/convolution" source_file="/home/elian
a/escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py" so
urce_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_queu
es":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRel
u","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
2025-06-11 17:30:13.528961: I external/local_xla/xla/service/gpu/autotuning/conv_
algorithm_picker.cc:549] Omitted potentially buggy algorithm eng14{k25=0} for con
v %cudnn-conv-bias-activation.11 = (f32[12,128,37,37]{3,2,1,0}, u8[0]{0}) custom-
call(f32[12,128,37,37]{3,2,1,0} %bitcast.604, f32[128,128,3,3]{3,2,1,0} %bitcast.
611, f32[128]{0} %bitcast.613), window={size=3x3 pad=1_1x1_1}, dim_labels=bf01_oi
```

```
01->bf01, custom_call_target="__cudnn$convBiasActivationForward", metadata={op_ty
pe="Conv2D" op_name="functional_1/conv2d_2_1/convolution" source_file="/home/elia
na/escola/venv/lib/python3.12/site-packages/tensorflow/python/framework/ops.py" s
ource_line=1200}, backend_config={"operation_queue_id":"0","wait_on_operation_que
ues":[],"cudnn_conv_backend_config":{"conv_result_scale":1,"activation_mode":"kRe
lu","side_input_scale":0,"leakyrelu_alpha":0},"force_earliest_schedule":false}
```

```
134/134 ━━━━━━━━━━━━━━━━━━━━ 21s 117ms/step - accuracy: 0.2012 - loss: 2.6406 - v
al_accuracy: 0.3761 - val_loss: 1.7970
Epoch 2/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 75ms/step - accuracy: 0.3649 - loss: 1.8279 - va
l_accuracy: 0.3824 - val_loss: 1.7203
Epoch 3/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 75ms/step - accuracy: 0.4562 - loss: 1.5968 - va
l_accuracy: 0.5014 - val_loss: 1.5018
Epoch 4/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 75ms/step - accuracy: 0.4565 - loss: 1.5350 - va
l_accuracy: 0.4937 - val_loss: 1.5870
Epoch 5/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.4896 - loss: 1.4763 - va
l_accuracy: 0.4859 - val_loss: 1.5297
Epoch 6/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5064 - loss: 1.4565 - va
l_accuracy: 0.5239 - val_loss: 1.4166
Epoch 7/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5205 - loss: 1.4138 - va
l_accuracy: 0.5204 - val_loss: 1.4242
Epoch 8/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5267 - loss: 1.3934 - va
l_accuracy: 0.5303 - val_loss: 1.4101
Epoch 9/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5485 - loss: 1.3694 - va
l_accuracy: 0.5401 - val_loss: 1.4273
Epoch 10/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5417 - loss: 1.3682 - va
l_accuracy: 0.5211 - val_loss: 1.4840
Epoch 11/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5489 - loss: 1.3862 - va
l_accuracy: 0.5683 - val_loss: 1.3896
Epoch 12/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5505 - loss: 1.3620 - va
l_accuracy: 0.5514 - val_loss: 1.3824
Epoch 13/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5514 - loss: 1.3423 - va
l_accuracy: 0.5507 - val_loss: 1.3785
Epoch 14/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5652 - loss: 1.2994 - va
l_accuracy: 0.5711 - val_loss: 1.3356
Epoch 15/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5737 - loss: 1.3215 - va
l_accuracy: 0.5373 - val_loss: 1.4878
Epoch 16/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5798 - loss: 1.3017 - va
l_accuracy: 0.5676 - val_loss: 1.3824
Epoch 17/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5748 - loss: 1.3161 - va
l_accuracy: 0.5845 - val_loss: 1.3897
Epoch 18/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5873 - loss: 1.3255 - va
l_accuracy: 0.5810 - val_loss: 1.4221
Epoch 19/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5878 - loss: 1.3199 - va
l_accuracy: 0.5690 - val_loss: 1.3955
Epoch 20/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5903 - loss: 1.3134 - va
l_accuracy: 0.5958 - val_loss: 1.3568
Epoch 21/25
```

```
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.5961 - loss: 1.3064 - va
l_accuracy: 0.5669 - val_loss: 1.4439
Epoch 22/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.6345 - loss: 1.2836 - va
l_accuracy: 0.5704 - val_loss: 1.4132
Epoch 23/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.6043 - loss: 1.2955 - va
l_accuracy: 0.5979 - val_loss: 1.3494
Epoch 24/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 76ms/step - accuracy: 0.6192 - loss: 1.2551 - va
l_accuracy: 0.5796 - val_loss: 1.3986
Epoch 25/25
134/134 ━━━━━━━━━━━━━━━━━━━━ 10s 77ms/step - accuracy: 0.6370 - loss: 1.2491 - va
l_accuracy: 0.5944 - val_loss: 1.4077
```

4 - Testar o modelo

In [25]:
```
print_classification_metrics(model, test_dataset, "Modelo 1 : CNN de raiz")
```

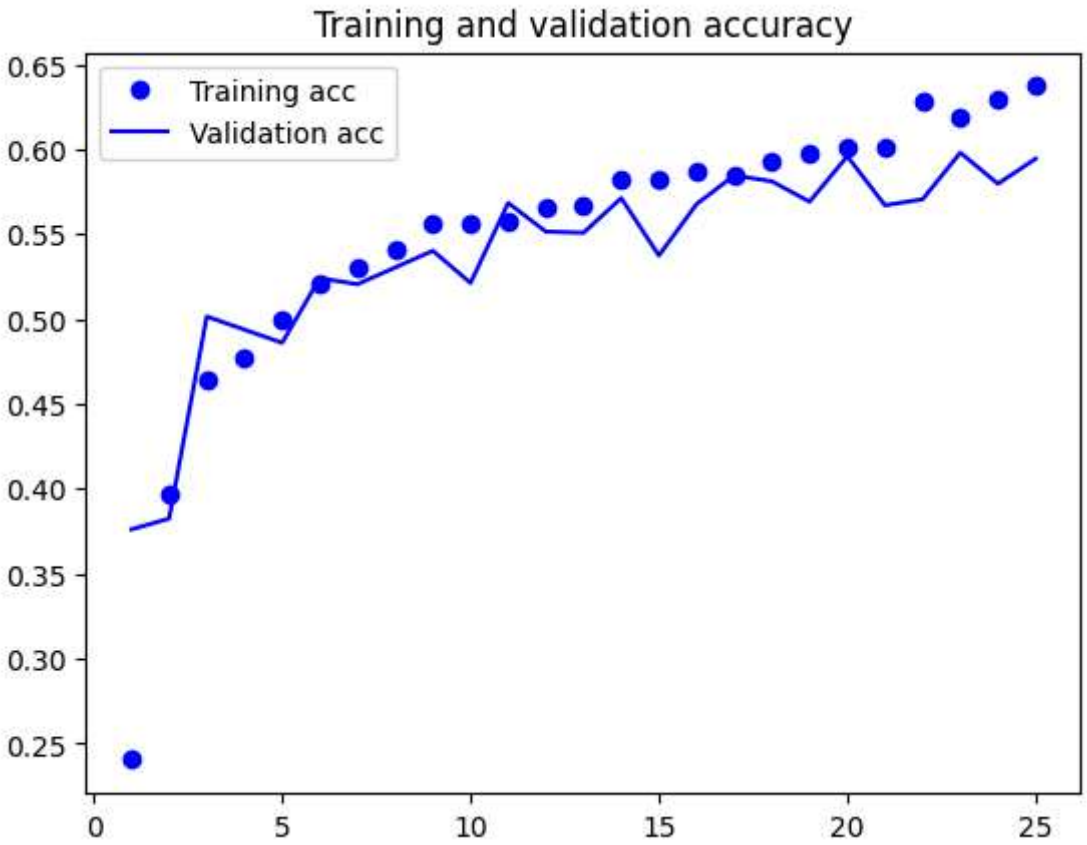
```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 332ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 55ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 54ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 55ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 54ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 57ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 58ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 54ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 54ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 55ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 55ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 57ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 55ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 56ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 54ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 54ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 301ms/step

 Modelo 1 : CNN de raiz
              precision    recall  f1-score   support

           0     0.4519    0.5538    0.4977       195
           1     0.5066    0.5808    0.5412       198
           2     0.5926    0.5845    0.5885       219
           3     0.7264    0.4010    0.5168       192
           4     0.5066    0.6892    0.5840       222
           5     0.7635    0.5650    0.6494       200
           6     0.9396    0.8814    0.9096       194

    accuracy                         0.6092      1420
   macro avg     0.6410    0.6080    0.6124      1420
```

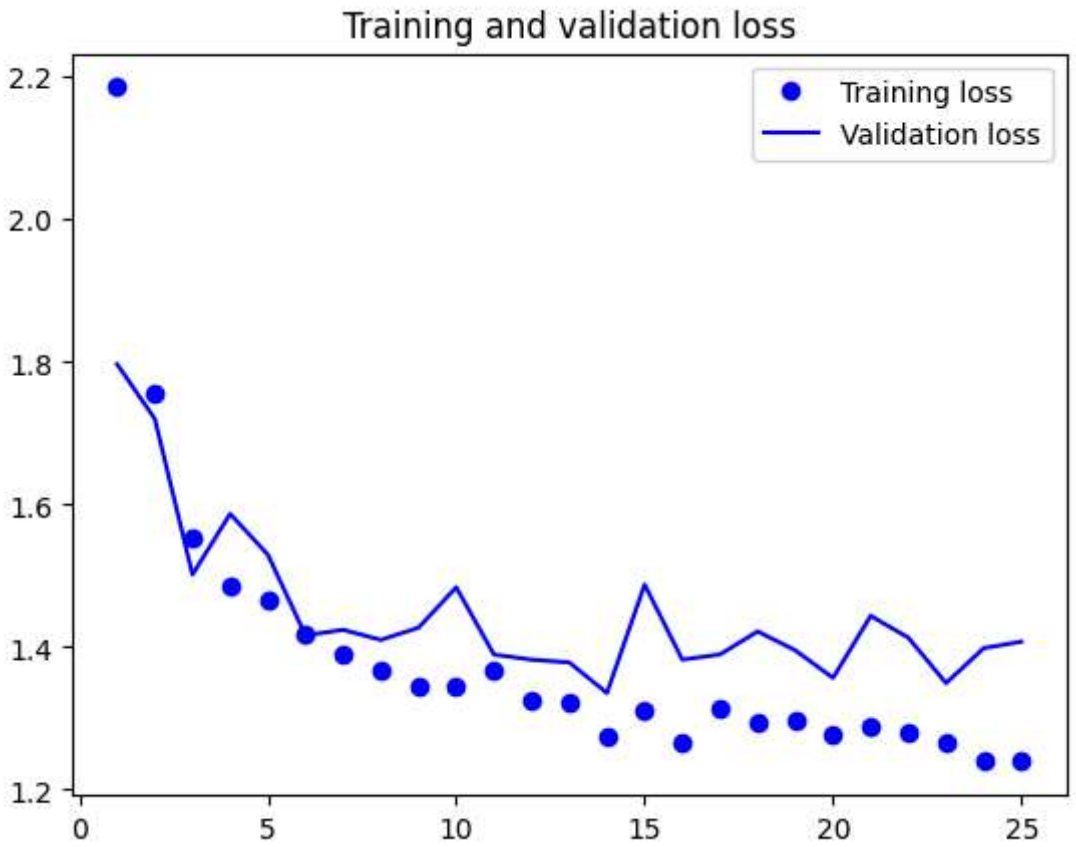
```
weighted avg      0.6374    0.6092    0.6115       1420
```

```
2025-06-11 17:34:22.390662: I tensorflow/core/framework/local_rendezvous.cc:407]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```

Ver as Curvas de Loss e de Accuracy

In [29]:
```
import matplotlib.pyplot as plt
accuracy = history.history['accuracy']
val_acc = history.history['val_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs = range(1, len(accuracy) + 1)
plt.plot(epochs, accuracy, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
plt.legend()
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```



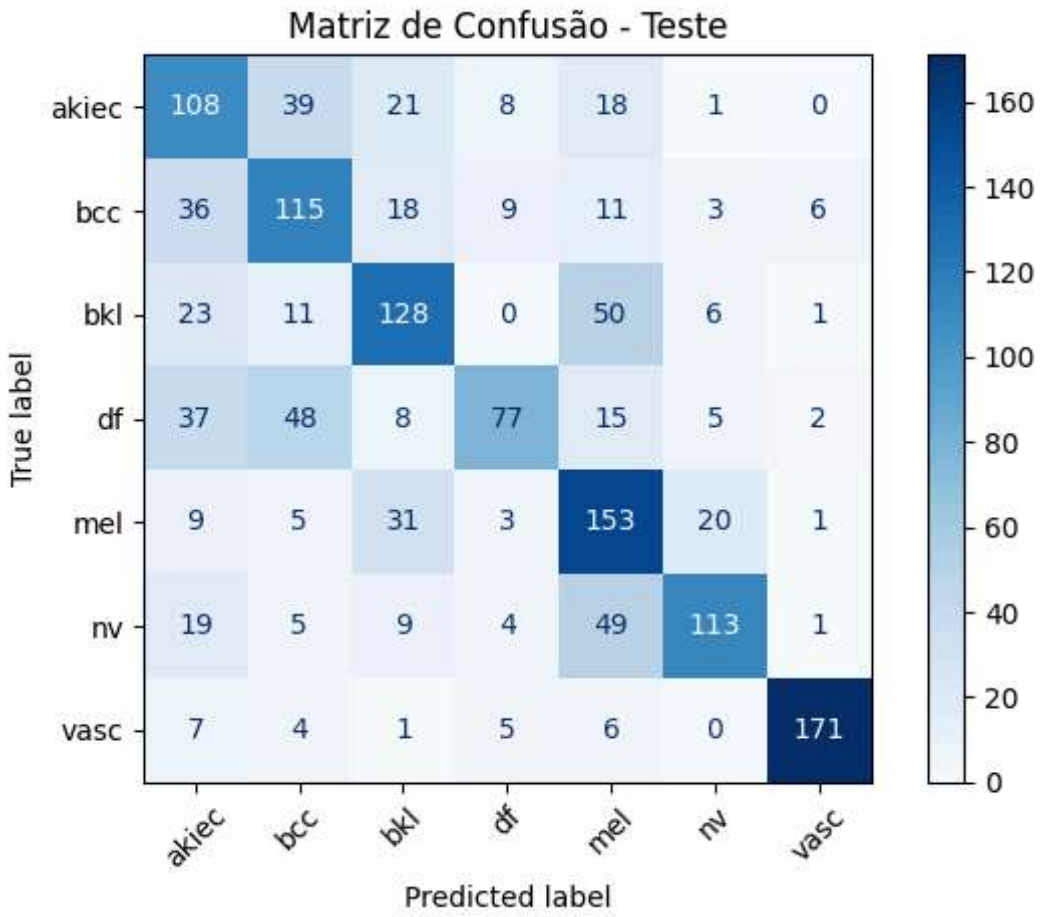


Este modelo mostra um comportamento estável e constante. As curvas acompanham-se bem, não há sinais de overfitting, e o número de épocas parece adequado. O treino está a ser bem aproveitado.

Matriz de confusão

In [32]:
```
import numpy as np
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
import matplotlib.pyplot as plt

# Obter predições no test_dataset
y_true = []
y_pred = []

for images, labels in test_dataset:
    preds = model.predict(images)
    y_true.extend(np.argmax(labels.numpy(), axis=1))
    y_pred.extend(np.argmax(preds, axis=1))

class_names = test_dataset.class_names

# Criar e mostrar a matriz de confusão
cm = confusion_matrix(y_true, y_pred)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=class_names)

plt.figure(figsize=(10, 8))
disp.plot(cmap=plt.cm.Blues, xticks_rotation=45, values_format='d')
plt.title("Matriz de Confusão - Teste")
plt.tight_layout()
plt.show()
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 75ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 86ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 74ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 68ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 82ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 74ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 68ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 81ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 75ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 64ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 80ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 71ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 92ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 71ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 63ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 81ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 74ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 67ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 83ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 73ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 64ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 85ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 74ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 66ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 84ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 70ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 66ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 84ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 71ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 66ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 81ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 73ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 65ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 82ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 70ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 69ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 82ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 72ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 66ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 73ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 81ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 71ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 65ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 86ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 48ms/step
2025-06-11 17:43:00.429192: I tensorflow/core/framework/local_rendezvous.cc:407]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
<Figure size 1000x800 with 0 Axes>
```



A matriz apresenta valores altos na diagonal, refletindo boa precisão nas predições corretas. As confusões entre df, bcc e akiec sugerem que o modelo tem mais dificuldade em distinguir lesões com aparência semelhante.

Salvar o modelo

In [31]:
```
model.save("modelS_2A_sem_data_aug_Adam.keras")
```